THE JOURNAL OF THE INDIAN BOTANICAL SOCIETY

Four numbers of the Journal will be published annually, in February, May, August and November, respectively.

Annual subscription to the Journal, Rs. 15 in India and £ 1–3–0 or \$ 5·50 abroad. Subscriptions should be sent to the *Treasurer and Business Manager*, Dr. A. C. Joshi, Department of Botany, Government College, Lahore.

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All matter intended for publication in the Journal should be sent to the *Chief Editor*, Prof. M. O. P. Iyengar, Triplicane P.O., Madras.

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The Journal of the Indian Botanical Society

(Formerly "The Journal of Indian Botany")

VOL. XXV] MAY, 1946 [No. 2

AN ECOLOGICAL STUDY OF THE VEGETATION OF THE BENARES HINDU UNIVERSITY GROUNDS

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Received for publication on August 4, 1945

I. INTRODUCTION

THE campus of Benares Hindu University is nearly a rectangular area measuring about two miles from north to south and about one and a half miles from east to west. It is situated on a level ground near the bank of the Ganges about three miles to the south of the city. Twenty-eight years back the area was thickly populated with agricultural and industrial people spread in several villages. It had then a vegetation characteristic of the surrounding country. A part of it consisting of mango groves, mounds and ponds can still be found in the original condition while most of it was destroyed and modified with the construction work. Now this area is under buildings, gardens, playgrounds, roads and farming. Around these, a variety of habitats occupied mostly by a meadow vegetation, which consists of nearly 300 species of flowering plants and which shows strong seasonal aspects, has developed. The results of a study of these, largely done in 1942–43, are presented in this paper in a more or less topographic sequence of the habitats.

The low-lying lands, which hold standing water for the duration of the rainy season or for a longer period, are included in a separate study (Misra, 1946). Therein the tests on soil and the relevant climatological data for the area for the period of this investigation are also given. A detailed list of the species for each of the habitats with their frequency-abundance in the rainy, the cold and the hot seasons, their sociability and plant cover wherever necessary, have been published elsewhere (Misra, 1945). The climate has been described yet in another study (Misra, 1944).

II. The Vegetation

1. *General characters*

The optimum temperature and moisture conditions for plant growth are obtained during the rainy season when the vegetation attains a luxuriant monsoon aspect. It declines rapidly in the following cold season on account of lower temperature, drying soil and increased biotic activities. Nevertheless, a new flush of growth from the underground parts of the perennial herbs is obtained in the beginning of the hot season due to rise of temperature ; but later, the increasing drought and biotic activities reduce the vegetation to a miserable hot season aspect.

Following the first fall of rains, the almost bare ground begins greening up in patches. The subsequent showers of the season, frequently falling in torrential downpour wash down much of soil and plant propagules from the sloping higher lands. Erosion of soil continues to be rapid here until an effective plant cover has grown to stabilise it, as later in the season. *Urochloa reptans* and species of *Panicum* grow up quickly from their seeds which were stored by ants in holes. *Evolvulus nummularius* and *Cynodon dactylon* having survived in stunted forms from the preceding hot season now spread over big areas. These are followed by the growth of a large number of seedlings and sprouting rhizomes as deeper layers of the soil get moistened. *Crotalaria medicaginea*, *Cassia tora*, *Bothriochloa pertusa*, *Dichanthium annulatum*, *Euphorbia* spp. and *Indigofera enneaphylla* are the chief among these. The sloping lands subject to much erosion get covered with *Aristida adscenscionis*. Dudgeon (1920) and Bor (1941) characterised it as a species of over-grazed areas, but here, there is always a high incidence of the species with alkaline soils exposed to heavy erosion ; the latter condition following undoubtedly, at many places, continued grazing. Its abundant growth on old walls where rainwater has corroded the mortar joints is a further proof of the contention.

As the grounds look green, a large number of women and children flock there from the surrounding villages and scrape all the plants indiscriminately, right through the surface soil. Hungry cattle are also let loose for grazing. But there is a continued growth of the plants from below the eaten-up shoots, the deep buried parts and the late germinating seeds. This tussle between the growth of the vegetation and its biotic destruction continues until by the beginning of August the villagers, finding enough to feed their cattle nearer home, stop visiting the grounds so frequently.

By the middle of the rainy season, the grounds are covered with a thick mat of vegetation on account of the rapid growth coupled with the decline of the destructive biotic factors. The grasses grow high to their full stature. The waterlogged areas are covered with *Echinochloa colona*, *Alternanthera sessilis* and a number of sedges. Local edaphic conditions and plant processes such as vigour and competition are best reflected by the vegetation, everywhere indeed, during this season.

Most of the species flower and fruit on getting longer hours of sunshine through a clearer atmosphere of September. Now a number of new species join the vegetation. Of these *Ammania baccifera* in wet places, *Oplismenus burmanni* and *Setaria intermedia* in shaded dry places and species of *Eleusine*, *Eragrostis* and Compositæ in the open are very characteristic. These newer plants are capable of growing on a soil which is losing water rapidly, and can successfully compete with the older plants of the preceding wet season.

The well-grown rainy season vegetation disappears as abruptly in the month of October as it came during the rains. This is not so much on account of the drier conditions and the competition as for the destructive biotic factors, especially scraping which becomes rapid once again. Indeed very few plants are left to wilt down on the drying grounds. Of these, *Crotalaria medicaginea* is the first to dry up. The grasses turn yellow and the other species look dull brown. The dried remains, if not already removed for fuel, are attacked by white-ants, which now come up on the surface in very large numbers. They cast behind a light, porous, calcareous and nitrate-rich puffy earth which is poor in organic matter.

The minimum temperature in the cold season seldom falls so low as to stop plant growth and the frost injuries to the crop plants reported once in many years, are never in evidence in the natural meadow vegetation. But, the desiccating winds and the drying soil together with grazing and scraping tell heavily upon it. These conditions train most of the perennial meadow species into slow growing, prostrate and tufted depauperate forms which possess small, coriaceous or pubescent and dull looking leaves. The plants are chiefly : *Indigofera enneaphylla*, *Euphorbia* spp., *Bothriochloa pertusa*, *Dichanthium annulatum*, etc., forming open communities. *Eleusine ægyptica* and *Paspalidium flavidum* also grow to similar forms before they are dried up in December. The occasional winter rains may brighten them up but very temporarily.

The increasing temperature in March and April activates both vegetative and flowering growths. *Convolvulus pluricaulis*, *Evolvulus alsinoides*, *Boerhaavia diffusa* and the grasses spread out in the fields, and the low-lying lands look happier with abundant growth of *Mollugo hirta*, *Polygonum plebejum* and *Cynodon dactylon*. The deciduous trees bear new foliage, and blossom. The old leaves which have been shed off, are blown by the wind and deposited in depressions or against taller herbs. These are sweeped off for fuel by some of the village folk for frying grains, and so the organic matter from this source is lost to the soil.

Conditions for plant growth become extremely severe during the following hot days. The moist plant tissues have now to live between a dry soil and a desiccating atmosphere. The moisture content of the soil at the surface may decrease even upto 0·1% in the open, and the extremely low humidity coupled with strong wind at a higher temperature during the afternoons, would heavily tax the water content of any plant tissue. Indeed, only the most drought-enduring species

survive this ordeal. It is not uncommon to notice many plants and even branches of trees drying up in the month of May when the maximum temperature may go upto 115° F. It actually shot upto 119° F. in 1942, and as the records were taken in shade, the temperature of the exposed ground might well have been 40–50 degrees higher than these figures (*cf.* Dudgeon, 1920). Hence the surviving species must be heat enduring too. They invariably show variations in their form as a result of metabolic and growth adjustments. Prostrate and tufted habits with dwarfening effects reduce them to depauperate forms which bear coarsely veined leaves with a thicker deposit of cutin. Folding and rolling up of the grass leaves and, wilting in others, are found for the most of the day. *Heliotropium strigosum* and *Trichodesma indica* may grow slowly drawing nourishment out of the older tissues which are now cast behind to dry off. The grasses too send out young shoots from the rhizomes in a similar fashion. Older plants of *Boerhaavia diffusa*, *Convolvulus pluricaulis*, *Vernonia cinerea*, *Indigofera enneaphylla* and *Euphorbia granulata* seem to live on the supplies present in their enormous root systems.

Even the thin and sparse vegetation of the hot season is grazed and scraped, thus leaving big areas of white, dry and loosened earth on the grounds. A few occasional drizzles in the season are but poor solace and only at this time, a few small gray patches remind of some vegetation not worth the name.

2. *Mounds*

The mounds are old deposits of earth about ten to fifteen feet high. They have a flat top of varying expanse and steep to gently sloping sides. Three types of these are found on the grounds. Type 1 is found either singly and then surrounded by cultivated land, or in chains around tanks in the southern part of the University. This type is very old. Its surface is strewn with "kankar" (nodules of calcareous material) and pieces of earthenware and tiles showing its proximity to former villages. Type 2 consists of ten-year old deposits of soil dug out for the foundation of the temple which is under construction in the heart of the University. Its surface is rough and channelled by gully erosion. Type 3 is lying in the middle west of the area. It consists of deposits of cinder and moulding casts of clay used for making brass utensils. This was once a site of the village industry. It is now well wooded with 10–30-year old trees of *Ficus glomerata*, *F. religiosa*, *F. bengalensis*, *Bombax malabaricum*, *Melia azadirachta* and *Holoptelia integrifolia*. The meadow growth on all the mounds is scraped and grazed.

Type 1 mounds have a carbonate rich (3) and highly alkaline soil (pH = 8·3–8·5) which is light coloured, well compressed and poor in moisture content (0·5% to 0·8% in the dry seasons). *Aristida adscenscionis*, d ; *A. funiculata*, cd and *Desmostachya bipinnata*, ld are the commonest species on the mounds. The former two species dry up at the end of the cold season when *Blepharis molluginifolia* and other minor species become exposed and now spread over to

bigger areas. *Enicostema littorale* though sparsely distributed on the top of the mounds, is quite characteristic species of the situation, in the wet season. The maximum plant cover grows upto 75% of the ground at the end of the rainy season after which time, it may go down gradually falling upto 10% in the hot season.

Type 2 mounds consist of soft sandy loam with an average pH value of 8·0. It is pale and brown in colour and less saline (carbonate = 1) than the previous type. It is nitrifying (diphenylamine test= 1), opened by earth-worms during the rainy season and retains moisture upto 5·7% just after this time. These qualities of the soil account for a rich meadow vegetation which may cover upto 90% of the mounds at the end of the rainy season and is never less than 10% even during the dry seasons, despite grazing and scraping. But *Saccharum munja* and *S. spontaneum* (the latter appearing in the rainy season) are fast taking possession of most of the area on account of efficient rooting of their rhizomes. *Dichanthium annulatum* is the dominant species on the flat tops, and the steep slopes carry *Aristida adscenscionis*, with more of *Tridax procumbens* in the unstable gullies cut by erosion. *Indigofera enneaphylla* is very abundant on this type of soil and stands grazing and scraping well.

Type 3 mounds carry the poorest vegetation on account of a coarse, dark coloured and loose substratum of cinder and grits. It has a pH value of 7·80, carbonates are absent and its nitrifying capacity is very low (= 1). Nevertheless, many species like *Peristrophe bicalyculata*, *Rungia parviflora*, *Achyranthes aspera* and *Urochloa helopus* grow well on the mounds during the rainy season. These are followed by *Oplismenus burmanni* and later by *Nepeta ruderalis*. They all stand shade, and growing together, cover 50% of the ground in the month of October. This vegetation, in view of the poor nature of soil, is sustained primarily by the rains and high humidity ; the latter maintained for some time after the wet period by the overtopping trees. For, it rapidly dries up going down to less than 5% cover when dry winds blow in the following cold season. Only *Achyranthes aspera*, *Vernonia cinerea*, *Justicia diffusa*, *Rungia parviflora* and a few minor species remain till the end of the cold season.

The vegetation of the 3rd type of mounds may be compared with that found in shaded parts on the other two types. The old, alkaline and compressed substratum of the first type bears *Bothricchloa pertusa* and species of *Sporobolus*, in abundance, under shade. Since these species grow characteristically in the open on flat lands having a soil similar to type I, their incidence here, under the shade, may be accounted for by a lack of competition by other species. Type 2 mounds under similar situations grow a number of characteristic shade loving species such as *Setaria* spp., *Desmodium* spp. and *Sida veronicæfolia*, and a few others like *Eragrostis tenella*, *Digitaria* spp., *Sporobolus* spp., *Manisuris granularis*, *Alysicarpus monilifer* and *Tridax procumbens* which do well in shade, only when growing on rich soils. *Peristrophe bicalyculata* seems to be more characteristic on a loose soil open to rapid erosion, but has a decided preference for shade, when growing

on more stable and richer soil. *Rungia parviflora* on mound 3, is a shade-species on sandy soil; and *Nepeta ruderalis*, by its occurrence on ash and also on organic deposits near villages, indicates a liking for potassium. *Oplismenus burmanni*, on the other hand, is a definite shade loving species growing on a sloping land. This tender grass has a rapid growth, but is easily ousted by other species on account of its weakness for moisture.

3. *Bunds*

Bunds of earth, carrying on their top pucka channels to lead water for irrigation, run in different parts of the University grounds. These were constructed about 5 years back by working up the surrounding soil to a height of 4–6 feet with sloping sides which are now covered by plants. Seepage water from the channels keeps the substratum locally moist, and here a good lawn has grown which is frequently grazed and scraped. The soil consists of a sandy brown loam which shows slight seasonal variations in its characters. It has an average pH value of 8·40, a moderate carbonate content (1) and a good nitrifying capacity (3). The water content varies from 6·7% in October to 1·5% in April.

Richness of the soil with regard to salts and moisture is chiefly responsible for a green appearance of the bunds throughout the year. The vegetation consists of a large number of species showing strong seasonal aspects. But *Croton sparsiflorus* has, by now, become the dominant species. Joshi (1934) saw it first in Benares on the bank of the Ganges, in 1931, and then reported its arrival in the United Provinces from the eastern part of the country. It has now spread throughout the University area and the town. It is chiefly associated with the construction of buildings, roads and canals, as the seeds are carried to these places with sand taken from the bank of the river; and this would explain its absence from the surrounding villages where such construction does not usually take place. *Cynodon dactylon* finds the sloping moist bund a very favourable habitat. On flat dry grounds or waterlogged soils it is unable to stand competition by other species. The same facts hold good for *Oplismenus burmanni* which covers shaded parts of the bund at the end of the rainy season.

4. *Waste grounds and deposits of building materials*

Small pieces of rough land, both in open and shaded situations, are often seen bearing taller herbs. Where the ground is smooth and moist, it is covered by a lawn also. These are subject to grazing and scraping as usual and so either the coarser taller plants are left out, or those which can regenerate quickly from their underground parts.

The actual number of species found in such regions is quite large and here, only those few are listed which give a definite aspect to the vegetation. Most of these are very gregarious in habit. *Cassia tora*, *Crotalaria medicaginea* and *Triumfetta neglecta* are especially prominent in the rainy season. *Anesomeles ovata*, *Hyptis suaveolens* and *Peristrophe bicalyculata* grow in shade, becoming attractively tall at the

end of the season. As these species dry up in the cold season the remaining lower ones like *Achyranthes aspera*, *Croton sparsiflorus*, *Amarantus spinosus*, *Ocimum bacilicum*, *Tephrosia purpurea*, *Scoparia dulcis*, *Sida rhombifolia* and *Vernonia cinerea* become more prominent. *Argemone mèxicana* appears late in the season. The lower meadow species are chiefly, *Bothriochloa pertusa*, *Dichanthium annulatum*, *Cynodon dactylon*, *Aristida adscenscionis*, *Paspalidium flavidum*, *Eragrostis* spp., *Sporobolus* spp., *Echinochloa colona*, *Digitaria* spp., *Eleusine* spp., *Cyperus* spp., *Kyllinga* spp., *Fimbristylis* spp., *Corchorus acutangularis*, *Echinops echinatus*, *Volutarella divaricata*, *Justicia diffusa*, *Tridax procumbens*, *Boerhaavia diffusa*, *Convolvulus pluricaulis*, *Euphorbia* spp. and *Indigofera enneaphylla*. *Triumfetta neglecta*, *Trianthema monogyna* and later, in the cold season, *Nepeta, ruderalis*, grow abundantly on heaps of organic matter.

A considerable part of the grounds in the south end of the University, is occupied by brick fields. These consist of a number of kilns surrounded by uneven land, as the latter was irregularly dug out for laying bricks. The older fields were abandoned about ten years back, and in the mean time a characteristic vegetation has come up.

The brick kilns consist of circular and oval trenches. These are about 6–8 feet deep and about 12 feet wide, and each surrounds a piece of land standing like an island. The outer margin of the trench is enforced with a 2–3 feet high sloping bund of earth in order to keep out drainage water, which might but for it collect into the ditch from the surrounding lands during the rains.

The soil of the kilns is much modified on account of baking operations which obtained here before. It is carbonate-free unlike the surrounding area, and possesses a moderate capacity of nitrification (1). The pH values fluctuate a little during the different seasons ; here only the average values are recorded. On the bund, it is a red brown sand with $pH = 7 \cdot 15$, and the island has a brown sandy loam with $pH = 6 \cdot 92$. The bed of the trench has developed now into a soil of the latter type with $pH = 6 \cdot 22$, though formerly it was baked into a red earth as found in the working kilns of to-day. Some coal powder may be found mixed with the soil throughout the area.

The three regions, though floristically distinct, bear equally rich growth during the rainy season on account of the soil being saturated with more than 20% water. The characteristic species of the bund are : *Aristida adscenscionis*, *Urochloa reptans*, *Tragus racemosus*, *Sporobolus* spp. and *Digitaria sanguinalis*, as indicators of soil erosion, and *Indigofera enneaphylla*, *Heliotropium strigosum*, *Boerhaavia diffusa*, *Convolvulus pluricaulis*, *Zornia diphylla*, *Dichanthium annulatum*, *Eragrostis* spp. and *Eleusine ægyptica*, as indicators of grazing and scraping. The islands being comparatively inaccessible, are less affected by the biotic factors, and hence, there grow a number of tree seedlings such as those of *Tamarindus indicus*, *Streblus asper*, *Azadirachta indica*, *Mitragyna parviflora*, *Zizyphus jujuba* and *Acacia arabica*, besides

Saccharum munja and a meadow. The bed of the trenches remains more humid and shaded along the walls. Here a larger number of ephemerals are found. The chief ones are : *Crotalaria medicaginea, Polygala chinensis, Aneilema nudiflorum, Oldenlandia pectinata, O. corymbosa, Vandellia crustacea, Bonnaya brachiata, Cyperus rotundus, C. compressus, Echinochloa colona, Eragrostis tenella, Fimbristylis diphylla, Panicum psilopodium, P. trypheron, Paspalum scorbiculatum, Juncellus pygmæus, Setria* spp., etc. *Saccharum munja, Saccharum spontaneum, Euphorbia* spp., *Rungia parviflora, Cynodon dactylon* and *Evolvulus nummularius* also grow here abundantly.

During the dry seasons the soil loses most of its moisture. The sandy bund in December had only 0·93% of water when the island had 1·08% and the bed of the trench as much as 3·40%. But, in spite of the differences in moisture content at this time, the vegetational cover is almost equal in the three cases, being 30 to 40%, on account of a continued growth of drought-enduring species in the drier regions where the perennials were more abundant, even during the rainy season. Species of *Blumea, Salvia plebeja, Gnaphalium indicum, Nicotiana plumbaginifolia, Argemone mexicana*, etc., come up more abundantly in the moist trenches, replacing the rainy season ephemerals.

The old brick walls around the trenches are broken at several places where now the earth is exposed and subjected to erosion during the rains. Since they are free from biotic disturbances these bear local patches of dense vegetation, especially in the crevices. *Lindenbergia polyantha, Chloris virgata* and species of *Ficus* are very characteristic of the brick paved walls, while *Digitaria sanguinalis, Aristida adscenscionis, Urochloa reptans*, and *Boerhaavia diffusa* are constantly found on the cutcha parts. The last named species comes out of root stocks penetrating to the walls from the surrounding higher bund.

The pitted area around the kilns forms a number of small pools during the rainy season. These are included in a separate study (Misra, 1946). Here the low and gently sloping meadowlands, as separated by small bits of the original land, will be examined. The species common to the whole of the area are : *Saccharum munja, S. spontaneum, Crotalaria medicaginea, Zornia diphylla, Digitaria* spp. and *Cynodon dactylon*. The higher lands are very much eroded showing out rounded grits, and bear an open vegetation consisting of the above-named species and *Aristida adscenscionis, Alysicarpus monilifer, Bothriochloa pertusa, Convolvulus pluricaulis, Polygala chinensis, Echinops echinatus* and locally, *Anesomeles ovata*. The lower sloping meadowlands lie on a pale brown loam with an average pH of 7·20, and besides the common species, possess such others as : *Scoparia dulcis, Fimbristylis diphylla, Paspalum scorbiculatum, Panicum psilopodium, Euphorbia hirta, Aneilema nudiflorum, Cyperus rotundus, Evolvulus nummularius, Desmodium triflorum* and *D. parvifolium*.

Building materials such as bricks, grit and sand have quite often remained deposited for a sufficiently long time to be overgrown by a vegetation. A comparative study of such habitats has been chiefly made on the temple grounds.

The plants growing on the brick heaps, are rooted either to the ground below or to the soil collected in between the bricks. The newer deposits show a growth of *Tridax procumbens*, *Bothriochloa pertusa* and *Justicia quinqueangularis*. The old deposits get many more species, besides these, such as *Achyranthes aspera*, *Dichanthium annulatum*, *Digitaria sanguinalis*, *Echinops echinatus*, *Bidens pilosa* and *Cynodon dactylon*. They all send out a number of flexible shoots growing out of the crevices.

The plants, growing on the deposits of grit and sand, are truly characteristic of the loose substratum. Their root systems are extremely deep, and the shoots are too rigid and coarse. *Tridax procumbens*, *Indigofera enneaphylla*, *Cynodon dactylon*, *Argemone mexicana*, *Solanum xanthocarpum* and *Calotropis procera* are found on the grits with varying frequency. On the sand, which has a pH value of 8·20, many more species besides those of the grit, grow. Of these *Saccharum munja*, *Euphorbia dracunculoides*, *Xanthium strumarium*, *Chrozophora rottleri*, *Cyperus rotundus* and *Alysicarpus monilifer* are quite characteristic. It is interesting to note that an old deposit of clay, on the grounds, does not show any of the above mentioned species. The clay has a pH value of 7·16 and is well nitrifying (2). Here the characteristic species are *Convolvulus pluricaulis*, *Merremia emarginata*, *Paspalidium flavidum* and *Tragus racemosus*. It may however, be noted that a few miles away from this area *Xanthium strumarium* is very abundant on clay, but only when it is in shallow regions becoming waterlogged during the rains.

5. *Along buildings and hedges*

The surroundings of the buildings including the flower beds and the hedges get infested with a large number of weeds, as they receive lapsing attention of the Mali, especially during the long vacations of the University. These include invasions from the neighbouring vegetation, as also many exclusive and characteristic species. The special circumstances of the habitat are : a high humidity, as the wind is checked, and a soil moistened by water from the flower beds and the buildings. The northern side of the high buildings provides a shaded aspect in contrast to the sunny aspect of the other sides.

There are narrow lanes lined by low cut hedges of *Justicia gendarussa* leading to the steps of the verandahs. These are only moderately frequented, as the main approaches to the buildings are from the other sides. Nevertheless, the soil is sufficiently compressed on account of treading. The following species are common to the sunny region : *Tridax procumbens*, *Bothriochloa pertusa*, *Evolvulus nummularius* and *E. alsinoides* with *Eleusine indica*, in the rainy season. The species common to the shaded lanes are : *Amarantus viridis*, *Nicotiana plumbaginifolia*, *Biophytum sensitivum*, *Gnaphalium* spp., *Oxalis corniculata*, *Potentilla supina*, *Rungia parviflora*, *Solanum nigrum*, *Desmodium triflorum* and species of *Setaria* in the rainy season, and *Ageratum conyzoides*, *Celsia coromandelina* and *Euphorbia geniculata* in the cold season. The species which are common to both the sunny and the

shaded parts are: *Euphorbia* spp., *Cyperus rotundus* and ***Eragrostis*** spp.

The characteristic species of the gravel walks are: ***Amarantus spinosus***, *Sida rhombifolia*, *Tridax procumbens*, *Digitaria longiflora*, *Euphorbia* spp. and *Launea nudicaulis* with *Chloris virgata* and ***Eleusine indica*** during the wet season.

Water, running down the drains of the laboratories, provide an inundated and stagnant habitat around these buildings. Here, in the open, the commonest species are: *Ficus* spp., *Striga euphrasiodes*, *Aneilema nudiflorum*, *Eclipta alba*, *Cyperus rotundus*, *Echinochloa colona*, *Fimbristylis miliacea*, *Panicum psilopodium*, *Cynodon dactylon*, *Portulaca oleracea* and *Trianthema monogyna*; and in the shade these are: *Amarantus viridis*, *Celsia coromandelina*, *Ficus* spp., *Aneilema nudiflorum*, *Commelina bengalensis*, *Eclipta alba*, *Oxalis corniculata*, *Potentilla supina*, *Rungia parviflora*, *Echinochloa colona*, *Cynodon dactylon* and *Solanum nigrum*.

The beds of flower and those of the hedges provide nutritive and moist substratum for the growth of a large number of weeds and tree seedlings under partial shade. The commonest species are: *Conyza ambigua*, *Euphorbia hirta*, *Scoparia dulcis*, *Solanum nigrum*, *Tridax procumbens*, *Cyperus rotundus*, *Eragrostis* spp., *Sida acuta*, *Bothriochloa pertusa*, *Eriochloa ramosa*, *Panicum psilopodium*, *Setaria* spp., *Cyperus rotundus*, *Acalypha* spp., *Euphorbia geniculata*, *Biophytum sensitivum*, *Oldenlandia corymbosa*, *Phyllanthus niruri*, *Physalis minima*, *Digitaria* spp. and *Blumea* spp.

The hedges provide a support to the following climbers which grow frequently during the rainy season: *Ipomea pestigridis*, *I. scindica*, *Clitoria ternatea*, *Convolvulus arvensis* and *Rhynchosia minima*.

6. *Roadside*

The University roads run for a total length of over twenty miles. These are generally 10–15 feet wide, and, except for short distances in the extreme south, they are pucka being constructed of pieces of flag stone. A few of these are built entirely of 'kankar' but in every case they are occasionally dressed with this material when in need of repairs. A level cutcha footpath, 6–9 feet in width, runs on either side of the road. This is followed by a 15–20 feet wide gradually sloping meadowland which ends into a 4–6 feet wide cutcha drain; the latter is meant for carrying away the rainwater. There is usually a row of about twenty years' old avenue trees on either side of the drain. A section of the roadside is shown in Fig. 1.

Heavy showers of rain wash the road, and the water rushes down the footpath and the meadowland into the drain. In doing so it carries with it the leachings of the 'kankar' as it is powdered by vehicular traffic on the road, thus enriching the soil of the lower levels with calcium and carbonates. On the loss of the calcareous matrix the stone pieces of the road are exposed.

When the roads are dry during the cold season, the traffic raises up dense clouds of dust which settle down on the neighbouring vegetation. Its deposit on the plants may be sufficiently thick to choke many of them to death, at the busier roads. *Cassia tora* seems to suffer especially on this account, as locally on the less frequented roadside it may still be found flowering and fruiting, and further, there is a certain rejuvenation of the dust-covered plants when washed clean by occasional rains. *Euphorbia hirta*, on the other hand, stands well a dust cover. However, in open and drier situations it becomes red coloured due to synthesis of anthocyanins in the tissues which suffer from a deficiency of nitrogen on account of its low absorption from a cool and dry soil.

The worn-out roads are repaired at this time. The silted drains are dug deeper and the earth so removed is deposited on the eroded footpath and meadowland. This causes local destruction of the vegetation, but it regenerates soon in the original form.

The 'loo' in the following hot season sweeps the dust off the road and causes some erosion of the soil from the meadowland too. This exposes the underground parts of the perennials, which now give out dwarfened shoots while the more extensive older branches are drying, breaking and blown up under their bases, thus leaving a bare swept ground between the smaller individual plants.

A line transect study of a typical roadside is given in Fig. 1 and Table I. Here the line is divided into ten parts, and the number of individuals belonging to each species as distributed on the different parts are recorded for August and December. It will be seen from such a study that the footpath, the meadowland and the drain have each a different set up of the vegetation. These are hence described separately.

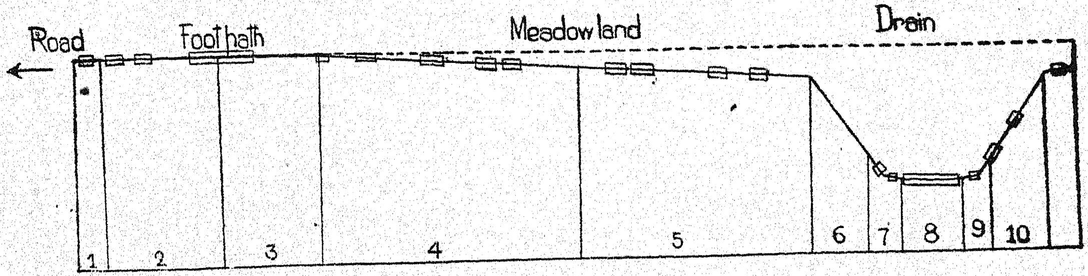

Fig. 1

Line transect across a typical roadside

Broken line=level of the road.

1–10 are the parts as given in the text.

Rectangles = areas without any plant on 28-8-'43.

TABLE I

A line transect study of a typical roadside

(The two horizontal rows of figures, for the cover and each of the species, correspond to records as obtained in August and December 1943)

Parts of the line	1	2	3	4	5	6	7	8	9	10
Cover (on 1–5 scale)	>1 >1	2 >1	4 >1	4 2	4 3	5 4	4 4	0 0	4 4	5 3
Paspalidium flavidum ..	1 Dry	18 ..	20 ..	3 ..	2 ..	2 ..	.. ..	.. ..	2 ..	3 ..
Urochloa reptans ..	.. Dry	5 ..	15 ..	57 ..	51 ..	2 ..	.. ..	.. ..	1 ..	10 ..
Indigofera enneaphylla ..	1 ..	.. ..	1 ..	9 12	7 17	7 5	.. ..	.. ..	.. ..	.. ..
Cyperus compressus ..	.. ..	1 ..	2 ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
Tribulus terrestris ..	.. ..	.. ..	1 ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
Cassia pumila ..	.. ..	.. ..	1 ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
Panicum psilopodium ..	.. ..	.. ..	.. ..	3 ..	1 ..	.. ..	.. ..	.. ..	.. ..	.. ..
Cynodon dactylon ..	.. ..	.. ..	.. ..	1 ..	.. 1	1 6	3 8	.. ..	2 2	2 12
Convolvulus pluricaulis ..	.. ..	.. ..	.. 2	.. 3	1 4	.. 2	.. ..	.. ..	.. ..	.. 3
Evolvulus alsinoides ..	.. ..	.. ..	.. ..	.. 1	.. 2	.. ..	.. ..	.. ..	.. ..	.. ..
Tragus racemosus ..	.. ..	.. ..	.. ..	.. ..	1 ..	.. ..	.. ..	.. ..	.. ..	.. ..
Alyscicarpus monilifer ..	.. ..	.. ..	.. ..	.. ..	1 ..	2 2	1 ..	.. ..	1 2	.. 2
Dichanthium annulatum	.. ..	.. ..	.. ..	.. 4	.. 12	6 5	.. ..	.. ..	.. ..	.. 5
Scoparia dulcis ..	.. ..	.. ..	.. ..	.. ..	.. ..	1 ..	.. ..	.. ..	.. ..	.. ..
Evolvulus nummularius ..	.. ..	.. ..	.. ..	.. ..	.. ..	1 ..	.. ..	.. ..	2 3	3 7
Cyperus rotundus ..	.. ..	.. ..	.. ..	.. ..	.. ..	1 ..	1 2	.. ..	.. ..	.. ..
Desmodium triflorum ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	1 ..	.. ..	1 2	.. 2
Alternanthera sessilis ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	1 ..	.. ..	.. ..	.. ..
Echinochloa colona ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	5 ..	.. ..	3 ..	.. ..
Vernonia cinerea ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. 3	.. ..	.. ..	.. ..	1 ..
Eragrostis tenella ..	.. ..	.. ..	.. ..	.. ..	.. 1	.. ..	.. ..	.. ..	.. ..	1 ..
Polygala chinensis .	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..	1 ..
Eleusine aegyptica ..	10 ..	12 ..	8 ..	2 6	1 6	.. ..	.. ..	.. ..	.. ..	.. ..
Euphorbia hirta ..	.. ..	.. ..	.. ..	.. 3	1 1	.. ..	.. ..	.. ..	.. ..	.. ..
Boerhaavia diffusa ..	.. ..	.. ..	.. ..	1 2	.. ..	.. ..	.. ..	.. ..	.. ..	.. ..
Indigofera linifolia ..	.. ..	.. ..	.. ..	.. ..	.. ..	1 ..	.. ..	.. ..	.. ..	.. ..

Footpath.—Pedestrians trample over the vegetation and kill it on the central track, while its growth is modified to varying extent on the outer side (*i.e.*, towards the meadowland) depending on the intensity of the operation. The inner side (*i.e.*, towards the road) of the footpath consists of the exposed stone pieces holding gravel and sand between them. It carries a sparse growth which is occasionally bruised and compressed by the road traffic. While the outer strip of the vegetation is scraped, the inner one is spared as the stony substratum is so unworkable.

The sand of the inner strip has a pH value of 7·84, carbonate = 2, nitrate = 1 and water content = 0·27%, in the month of October. The characteristic species of this region are: *Digitaria longiflora*, *Cynodon dactylon*, *Indigofera enneaphylla* and *Euphorbia* spp. with depauperate forms of *Paspalidium flavidum* and *Eleusine ægyptica* growing abundantly during the rainy season. The vegetational cover is very meagre and almost disappearing during the dry seasons.

The outer strip consists of a pale sandy loam enriched with the calcareous matter washed out of the road. Its pH value is 8·56, carbonate = 3, nitrate = 1 and water content = 0·89%, in October. It shows great seasonal difference in the vegetation. *Paspalidium flavidum*, in a depauperate form, is the dominant species of the vegetation during the rainy season. *Eleusine ægyptica*, *E. indica*, *Sporobolus* spp. and *Urochloa reptans* are characteristic associates, and *Tragus racemosus* and *Tribulus terrestris* are almost exclusive to this region. Most of these plants die off during the cold season, when species of *Euphorbia*, *Indigofera enneaphylla*, *Convolvulus pluricaulis* and *Evolvulus alsinoides* give to it an entirely changed aspect. This strip might be eroded down to the level of the meadowland by the end of the rainy season, and now, on account of the similarity in vegetation, they merge completely into each other.

Meadowland.—The sloping meadowland consists of a loam mixed with fine sand, and is full of earth-worms during the rainy season. Its pH value is 8·36, carbonates = 2, nitrates = 2 and water content = 1·03%, in the open, and 11·54% in the shade of the trees, at the same time in October. It bears a rich meadow vegetation which is denuded frequently by scraping and grazing.

The characteristic species of the open are: *Alysicarpus monilifer*, *Bothriochloa pertusa*, *Croton sparsiflorus*, *Desmodium triflorum*, *Eupharbia hirta*, *Indigofera enneaphylla*, *Orthosiphon pallidus* and *O. rubicundus*, *Urochloa reptans*, *Paspalidium flavidum* and *Evolvulus nummularius* appear abundantly during the rainy season, and *Convolvulus pluricaulis*, *Evolvulus alsinoides*, *Euphorbia prostrata*, *E. thymifolia* and *E. granulata* become more abundant during the dry seasons. The average plant coverings in the rainy, the cold and the hot seasons are 90%, 50% and 25% respectively.

The species of the shaded parts are: *Echinochloa colona* and *Commelina bengalensis* during the rainy season, *Eragrostis tenella*, *Oplismenus burmanni*, *Rungia parviflora* and *Setaria intermedia* in the

latter part of this season and the cold season, and *Cynodon dactylon* and *Sporobolus* sp. continuing to grow throughout the year. The average plant coverings for the three seasons, beginning from the rainy season, are 100%, 80% and 35%.

Drains.—The system of drains running along the roads, carry away rainwater from the whole of the grounds and as its bulk increases, they are dug wider and deeper towards the north. They remain dry, except during the rains when inundated by flowing drainage water. During the rainy season some water may be held up, in pits formed at the bottom, or bound by landslides, thus forming small pools. These are included in a study of the lowlying lands (Misra, 1946).

The drain wall is sloping unless cut vertical by rapid erosion as in the north. Where the latter condition obtains during the rainy season, very few species such as *Evolvulus nummularius* and *Cynodon dactylon* are found taking root on the surface as they hang down along the edge. Where erosion is moderate these are joined by *Urochloa reptans*, *Echinochloa colona* and *Cyperus rotundus*. In the upper parts where erosion is only periodical, following heavy rains, the wall is fully covered with these, and *Aristida adscenscionis*, *Alysicarpus monilifer*, *Bothriochloa pertusa*, *Desmodium triflorum* and *Indigofera enneaphylla* give it a meadow aspect. In the following dry seasons the drain wall bears the same vegetation as the flanking meadowland.

The bottom of the drain remains saturated with water for the most of the rainy season. The soil is finer here with pH = 7·70, carbonates = 1, nitrates = 2 and water content = 16·30% in October. It gets sparsely covered with *Urochloa reptans* in the beginning of the rainy season but later, the plants get choked with mud and water. The vegetation following it, consists of a mixture of marsh and meadow species ; the latter continue to live for the dry seasons. The characteristic marsh species are : *Alternanthera sessilis*, *Ammania baccifera*, *A. peploides*, *Cyperus rotundus*, *Commelina nudiflorum*, *Cyanotis axillaris*, *Cæsulia axillaris*, *Echinochloa colona* and *Fimbristylis miliacea*, and the commonest meadow species are : *Cynodon dactylon*, *Fimbristylis diphylla*, *Evolvulus nummularius*, *Aneilema nudiflorum*, *Bonnaya brachiata*, *Vandellia crustacea* and *Merremia emarginata*. During the dry seasons, the deeper parts which held water for a longer time in the rainy season get, besides the meadow species, *Sphæranthus indicus*, *Gnaphalium* spp. and *Mollugo hirta*.

The cutcha roads as found in the south of the grounds bear many of the wasteland species but the following are quite characteristic : *Digitaria royleana*, *Eleusine ægyptica*, *E. indica* and *Paspalidium flavidum* during the rainy season, and *Echinops echinatus*, *Volutarella divaricata* and *Solanum xanthocarpum* during the dry seasons, and *Cynodon dactylon* throughout the year.

7. *Playgrounds*

The plants growing on the extensive and flat playgrounds of the University are subject to immense treading by a large number of

players during the working terms and periodic scraping and grazing during the vacations. The hockey, the tennis and the volleyball courts are especially prepared for the games. In doing so, the vegetation is completely removed save the underground root stocks which might be deeply buried. These gradually send up shoots, and as soon as the pressure of the games declines, the fields tend to go wild with the germination of viable seeds and colonists from the neighbouring lands joining these.

The soil of the football fileds is an alkaline (pH $= 7 \cdot 5$–$8 \cdot 0$) light coloured loam giving a positive test for carbonates. It is kneaded and compressed by the activity of the players, and the compactness and efficient drainage may account for its low moisture content which was found to be $1 \cdot 5\%$ in September and only $0 \cdot 1\%$ in April.

In the beginning of the rainy season, *Urochloa reptans*, *Evolvulus nummularius*, *Cyperus rotundus*, *Indigofera enneaphylla*, *Heliotropium strigosum*, *Orthosiphon rubicundus*, *Cynodon dactylon*, *Desmodium parviflorum*, *Zornia diphylla* and *Eleusine ægyptica* grow into a good lawn under the pressure of players' feet. The less frequented parts are covered with a turf of *Sporobolus* spp., *Dichanthium annulatum* and *Eragrostis* spp., growing in bunches along with the ephemerals. In the following dry seasons *Convolvulus pluricaulis*, *Evolvulus alsinoides* and *Boerhaavia diffusa* grow profusely with their rose, white, blue and pink coloured flowers presenting a beautiful aspect in the early hot season.

The moister places are generally covered with *Aristida adscenscionis*, *Panicum trypheron*, *Eragrostis elongata*, *Cyperus* spp., etc., during the rainy season, but later become barren and remain so for the rest of the year. This is due to alkali salts from the leachings of the surrounding land being deposited there on drying. In presence of humus and algal growth, the earth breaks up into dark gray flakes which disintegrate later leaving white patches below. Species of *Luphorbia* and *Indigofera enneaphylla* may be found making a poor growth on this saline soil during the dry seasons.

The cutcha tennis courts are prepared by levelling, rolling and finally coating the ground with cowdung. When the courts are not in use during the hot season, *Trichodesma indica*, a ; *Boerhaavia diffusa*, o ; *Convolvulus pluricaulis*, o ; *Evolvulus alsinoides*, f ; and *Euphorbia hirta*, r come up from their buried parts (Fig. 2). In doing so they open the soil, as it is more efficiently done by black ants which pile up loosened earth around their holes. Now, with the occasional showers of rain, it becomes favourable for the germination of seeds of many other weeds and for the growth of more deeply buried rhizomes as those of *Desmostachya bipinnata*. By the end of the rainy season the courts get fairly covered with a vegetation of the following composition: *Convolvulus pluricaulis*, o ; *Boerhaavia diffusa*, o ; *Desmostachya bipinnata*, r–o ; *Eleusine ægyptica*, f ; *Euphorbia hirta*, o ; *Eragrostis elongata*, f ; *Eragrostis tenella*, o ; *E. viscosa*, o ; *Scoparia dulcis*, r ; *Tribulus terrestris*, o–f ; *Trichodesma indica*, o ; *Urochloa reptans*, f ; and *Vernonia cinerea*, r.

The volleyball grounds bear chiefly, *Scoparia dulcis*, f; *Pulicaria crispa*, o; *Eragrostis* spp. and a few of the tennis court elements, in the hot season. These are scraped off in July for the game. The hockey fields tend to grow more like the football fields whenever these are not much in use.

8. *Grasslands*

Several acres of grassland surround the College buildings, as the land is enclosed for the purpose of developing garden and lawn. The soil consists of a light brown loam rich in carbonates (= 3) with pH = 8·35. Nitrate content is moderate and the water content in April is as low as 0·64%.

Bothriochloa pertusa and *Dichanthium annulatum* growing upto a height of 4 feet, during the rainy season, almost fill up the areas. The more neglected parts are dotted with young trees of *Acacia arabica*. The grasses are mowed for hay in September or October; they grow, thereafter, prostrate forming agreeable lawns. The following subordinate species are exposed on the removal of the top growth when they do better: *Rhynchosia minima*, *Indigofera enneaphylla*, *I. linifolia*, *Boerhaavia diffusa*, *Euphorbia* spp., *Cynodon dactylon*, *Evolvulus alsinoides* and *Convolvulus pluricaulis*. Another but poorer crop of hay is obtained at the end of the cold season if the land has been kept free of grazing and scraping. The study shows how a little planning, by affording periodical protection to the lands against the biotic factors, would improve the meadowlands. However, continued protection leads to a deterioration of the grasses as they are strangled by the twining of *Rhynchosia minima* which grows rapidly even during the dry seasons. It has been so observed in one of the experimental plots.

Local depressions in the grasslands bear a vegetation similar to those of the football fields, except that here, *Digitaria royleana*, *Cynodon dactylon* and a few others continue to grow for the dry seasons as the salinity does not increase very much.

The foot tracks are covered with *Paspalidium flavidum*, va; *Tribulus terrestris*, f; *Sporobolus wallichii*, a; *Cynodon dactylon*, f; and *Euphorbia* spp., of. Only the first two elements disappear during the dry seasons.

Such a grassland does not ordinarily develop in shade, but, under the mango groves in the south of the grounds where direct light is obtained in the form of moving sunflakes, a grassland of *Imperata cylindrica* is obtained. The species remains in a depauperate form on account of frequent grazing and scraping. The soil has an average pH value of 7·21 and is well nitrified (= 2). The following associate species are found here: *Paspalidium flavidum*, *Paspalum scorbiculatum*, *Bothriochloa pertusa*, *Desmodium gangeticum*, *D. parvifolium*, *D. triflorum* and *Rungia parviflora*.

There is a very sparse growth at the base of the tree boles. This may be so on account of the seeds being washed off by the rainwater

dripping along them, and also presumably due to a large population of ants which live on the tree and feed upon the grass seeds. *Oplismenus burmanni*, a ; *Evolvulus nummularius*, f ; and *Sida veronicæfolia* are the only species which easily creep up to these situations.

9. *Sir Gangaram Canal*

A beautiful pucka canal, named after Sir Gangaram, was built in the centre of the University, in 1936. It is a fifty-feet wide structure, and runs in an oval shape around the temple ground for a little more than three furlongs in total length. It is bound by six-feet high walls, and the bottom has a slope of 1½ feet towards the middle. Some sand was deposited on it as the bottom became slippery for bathers on account of algal growth. But it all accumulated in the middle deeper part due to the slope. After working it for three years when it was served by tube wells fitted with electric pumps, the canal was abandoned as the filling was found to be too expensive. Now in the dry condition, the bottom has cracked at numerous places. The sand and the cracks have provided landing grounds for plant colonists. Of these *Saccharum munja* is very aggressive and destructive to the canal bottom. Its rhizomes growing out of the sand run higher up at the sloping bottom and send down roots on coming across a little hole. Here the plant grows in a tussock cracking up the cemented substratum extensively, and sends out some more rhizomes to repeat the process elsewhere. The cracks are further widened by a host of species among which *Tridax procumbens* is abundant. Undisturbed by th biotic factors, this vegetation is rapidly growing on the ruins of the canal (Fig. 3). It has a luxuriant aspect on the gray sand deposits during the rainy season, but it is abruptly reduced in the following dry seasons when the few remaining drought-enduring species alone are found rooted to the crevices.

The strip of sand lying in the middle is 4–6 feet wide and about 6 inches deep. Rainwater collecting here runs into two pools situated at the ends of the canal. When enough has accumulated to fill them up during the rainy season, the strip of sand is also covered with it at the middle, which gets exposed only at longer intervals of drought. Even so, and despite the thinness of the deposit, the sand remains almost continuously saturated with water in the season as little could be lost by percolation—there being the cemented bottom. The high moisture content of the sand sustains a growth of closed grass-sedge community which reduces surface evaporation and improves the water-retaining capacity of the substratum by adding humus to it. It has actually turned gray on the same account. Its moisture content fluctuates between 28·5–2·80% from July to September. In the dry seasons it goes down to 0·8–0·23%. The cement and the mortar, weathering out into the sand, make it highly alkaline and saline. The pH value is found to be between 8·02 and 8·36, and the carbonate content = 4. Its nitrifying capacity is low being locally perceptible upto 1.

The rainy season vegetation on the sand shows out a central wet zone which remains covered with water for a longer time and

a marginal drier zone. The central zone is characterised by the following growth : *Ammania baccifera*, o ; *Alternanthera sessilis*, o ; *Cyperus* spp., o ; *Echinochloa colona*, d ; *Fimbristylis podocarpa* and *F. diphylla*, o ; *Juncellus pygmæus*, lf ; *Paspalidium flavidum*, lf; *Saccharum spontaneum*, o ; *S. munja*, o ; *Eragrostis* spp., cd–la ; and *Cyperus rotundus*, la. Only the last four species live till the month of January when they are joined with a growth of *Cynodon dactylon*, o ; *Portulaca oleracea* and *P. quadrifida*. By the end of April only these three, with *Saccharum munja* and a few plants of *Evolvulus alsinoides* are found in this zone.

The marginal vegetation on the sand has the followiig composition : *Aristida adscenscionis*, r–o ; *Achyranthes aspera*, o ; *Cyperus compressus*, lf ; *Paspalidium flavidum*, lf ; *Cyperus rotundus*, la ; *Eragrostis* spp., f–la ; *Eleusine ægyptica*, o ; *Justicia quinqueangularis*, lf ; *Saccharum spontaneum*, o ; *Sporobolus* spp., f ; and *Scoparia dulcis*, r during the rainy season ; the last seven species and *Alysicarpus monilifer*, r–o ; *Portulaca* spp., lf ; *Euphorbia prostrata*, o and *Vernonia cinerea*, o—during the cold season, and only these four continuing till the end of the hot season. *Saccharum munja*, f and *Cynodon dactylon*, o are found throughout the year.

At one place in the dry canal, water has been trickling from a leaking pipe which ran over it to supply for the construction of the temple. Here a more lasting and closed plant community, consisting chiefly of the grasses and the sedges, has developed (Fig. 4). It has substantially modified the characters of the substratum in as much as the pH value has gone down to 7·86 and the sand has become darker and softer with humus. The vegetation consists of : *Echinochloa colona*, la ; *Fimbristylis* spp., o–la ; *Juncellus pygmæus*, lf ; *Ishcæmum rugosum*, o during the rainy season, *Alternanthera sessilis*, lf ; *Blumea lacera*, o ; *Eragrostis* spp., o–lf ; *Justicia quinqueangularis*, f–la growing in the rainy and the cold seasons, *Sphæranthus indicus*, r, coming up in the cold season but continuing till the hot season, and *Cyperus* spp., f–la ; *Cynodon dactylon*, f ; *Eclipta alba*, o ; *Saccharum munja*, f and *Scoparia dulcis*, r, grow for the whole of the year. Most of these plants would not be found on the sand but for its higher moisture and humus content.

Wherever a little soil from outside has accumulated on the bottom of the canal, a very different colony of plants is to be found in the rainy season. The commonest species are : *Tephrosia purpurea*, *Corchorus acutangularis*, *Cassia tora* and *Urochloa reptans*. *Calortopis procera* grows for the whole year on thicker deposits of soil.

The cracks on the bottom are inhabited by *Saccharum munja*, d ; *Tridax procumbens*, *a* ; *Cynodon dactylon*, o ; and *Sporobolus* spp., f ; *Eleusine indica* and *E. ægyptica*, f ; *Eragrostis* spp., f ; *Scoparia dulcis*, o, during the rainy and the cold seasons, and *Portulaca* spp., lf, in the dry seasons.

Grasses like *Bothriochloa pertusa*, *Dichanthium annulatum* and species of *Digitaria* grow only on the sand and soil held on the tussocks

of *Saccharum munja* forming a distinct plant cummunity. These plants seem to be susceptible to the high carbonate and calcium content of the canal bottom. The other species as found on the pucka substratum must then be strongly calcicolous.

10. *Weeds of cultivated lands*

A good part of the University grounds is under cultivation. Almost all the principal crops are raised here. The typical weeds of these as associated with the rainy season crops (Kharif) and the cold season crops (Rabi) are listed below. The weeds are well equipped for distribution and growth under the cultural operations and many of them are exclusive to the areas, being ousted from elsewhere by the native species which are more aggressive there.

KHARIF

**Cyperus rotundus*
C. compressus
Juncellus pygmæus
Pycerus pumilus
Scirpus squarrosus
Fimbristylis diphylla
Digitaria sanguinalis
D. royleana
Eleusine aegyptica
E. indica
**Eragrostis tenella*
E. pilosa
Sporobolus wallichii
**Desmostachya bipinnata*
Bonnaya brachiata
B. veronicæfolia
Vandellia crustacea
Oldenlandia paniculata
O. corymbosa
Trianthema monogyna
**Portulaca oleracea*
**Convolvulus arvensis*
Cleome viscosa
Gynandropsis pentaphylla
Physalis minima
Corchorus acutangularis
Sesbania aculeata
Lochnera pusilla
**Aerua scandens*
Digera arvensis
**Striga euphrasiodes*
**Leucas aspera*

RABI

Asphodelus tennuifolius
Chenopodium album
Euphorbia dracunculoides
Anagallis arvensis
Saponaria vaccaria
Vicia sativa
Melilotus alba
M. indica
Medicago lupulina
Lathyrus aphaca
L. sativa
Amarantus spinosus
A. viridis
Argemone mexicana
Launea nudicaulis
Canscora decussata
Echinops echinatus
Volutarella divaricata
Orobanche ægyptica
O. cernua
Blumea spp.
Solanum nigrum

Also those marked with an asterisk (*) under Kharif

The weeds of the rice fields are those generally found on low-lying lands. The characters of such habitats have been described by Misra (1946). The more important species are listed below :

Ammania baccifera
A. peploides
Aponogeton spp.
Caesulia axillaris
Cyanotis axillaris
Cyperus digitatus
C. exaltatus
Echinochloa colona
E. crus-galli
Glossostigma spathulatum
Hemarthria compressa
Hydrolea zeylanica
Hygrophila polysperma
Ischæmum rugosum
Ludwigia parviflora
Manisuris granularis
Mariscus compactus
Oryza sativa
Panicum proliferum
P. humile
P. psilopodium
Paspalidium geminatum
Sesbania aculeata

When the fields are dry and the crop has been removed, the following species come up :

Cynodon dactylon
Dichanthium annulatum
Eragrostis interrupta
Grangea maderaspatana
Hydrolea zeylanica
Iseilema laxum
Scirpus articulatus
S. michælianus
Sphæranthus indicus

III. Discussion

The vegetation of the grounds owes its existence to human activities. These are chiefly: scraping and grazing, construction of buildings, roads, canals, etc., traffic and cultivation, producing the different types of communities as described in the text. The grounds are frequently denuded of the plant cover, and soil conditions are altered by these operations which also play a continuous selective role on fresh invasions and colonisations, and induce quite often variations in the form of the species. This is how the communities are actually shaped. Big drifts in soil moisture and temperature during the year are mainly responsible for the contrasting seasonal aspects. While batches of annuals come up and die the perennials resume growth, show habit variations and may even lose their shoots with a change of the seasons. The component species of the community, growing together but at different stages of their life-cycle, add to the diversity of a highly heterogeneous assemblage of plants. Indeed, the vegetation of a locality in two different seasons is more unlike than that of two dissimilar localities at the same time. But, since the seasons with all their effects are recurrent, the vegetation of any locality has to be viewed as a whole throughout the year. It is only in this way that a changing habitat with the changing vegetation of a locality can be brought together in a line, through the seasons. For the characterisation of such a plant community, the perennials should especially be taken into account, though the annuals may become dominant at times as in more denuded areas.

In a study of the low-lying lands Misra (1946) took a different view in proposing a 'hydrosere' and a 'xerosere' as proceeding at the same place but at different times of the year, where entirely different plant communities grow in water and on the dried up bottom each year depending not so much in the former case on seasons as on the depth of water. But here in the present case, a matrix vegetation, howsoever small, consisting of a few perennials is always found on the ground throughout the year, despite the diversity of the seasons. Hence different lines of succession need not be drawn in this case; even so, it becomes unthinkable in a higher community, such as a forest where a situation like this does not arise as the exigencies of the seasons are mainly met by changes in the shoots of the dominant trees, and here the destructive biotic factors become subordinate to the growing community.

The status of the meadow vegetation in this area is therefore a disclimax in the terms of Weaver and Clements (1929). The meadow associes is characterised by the following species: *Dichanthium annulatum*, *Indigofera enneaphylla*, *Boerhaavia diffusa*, *Euphorbia hirta*, *E.* spp., *Cynodon dactylon*, *Evolvulus alsinoides*, *Convolvulus pluricaulis*, *Justicia diffusa* and locally *Rungia* sp.

IV. Summary

The vegetation as found in the various habitats of the grounds of Benares Hindu University, covering an area of about three square

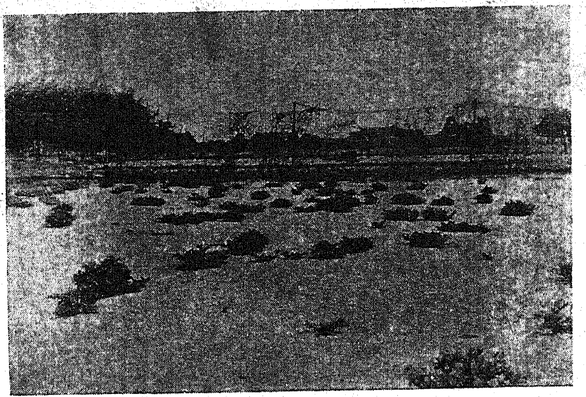

FIG. 2

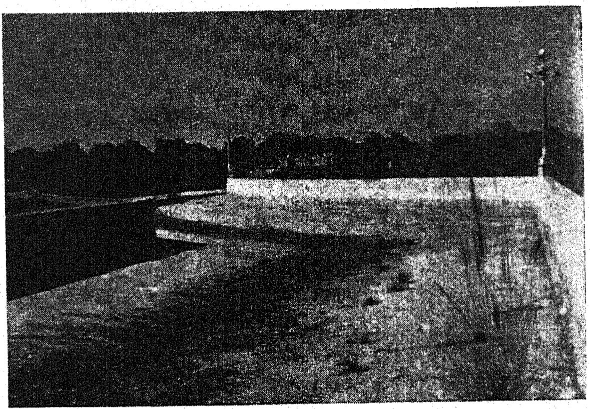

FIG. 3

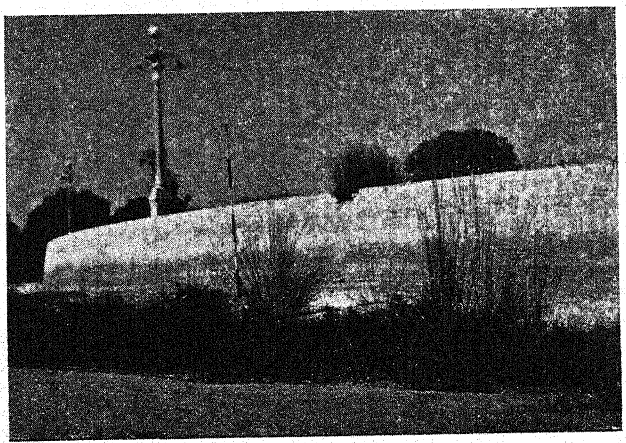

FIG. 4

R. MISRA—
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miles, is described. The different factors controlling its growth in the three seasons have been analysed with a special study of the soil.

Many facts of ecological importance and emerging problems are noted in the study.

It is concluded that the meadow vegetation which is largely controlled by human activities is a disclimax in this area.

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ON THE OCCURRENCE OF MICROSPORES IN SOME CENTRIC DIATOMS OF THE MADRAS COAST*

By R. SUBRAHMANYAN, M.Sc.

Received for publication on September 24, 1945

THERE have been several records of microspore-formation among Centric Diatoms. Fritsch (1935, pp. 633–38) and Smith (1933, pp. 205–6) have given a brief account of all the various records of microspores by different workers and the different views expressed by these authors regarding the nature of these microspores. Since then, a few more records of microspore-formation have been made (Majeed, 1935; Gross, 1937/38; and Braarud, 1939). Conflicting opinions have been expressed regarding the exact nature and role of these microspores in the life-history of the Diatom, *viz.*, (1) that they represent the gametes of the Diatom, (2) that they are not gametes but asexual reproductive bodies intended for the multiplication of the Diatom, and (3) that they are not reproductive structures of the Diatom at all, but are only foreign parasites or abnormal products of the Diatom cell playing no part in its life-history. The writer does not propose to go into the question of the nature and role of these microspores here. He merely wishes to record here some cases of microspore-formation that he came across while investigating the marine plankton Diatoms of the Madras coast. There does not appear to be any record of microspore-formation in the marine Diatoms of India so far. Altogether this phenomenon was observed by the writer in six forms from the Madras Coast, viz., *Coscinodiscus* sp., *Actinocyclus Ehrenbergii* Ralfs, *Chætoceros Lorenzianus* Grunow, *Bellerochea malleus* (Brightwell) Van Heurck, *Biddulphia mobiliensis* Bailey and *Cerataulina Bergonii* Peragallo. Of these, microspore-formation has already been recorded from outside Indian waters in *Coscinodiscus* (Murray, 1896; Karsten, 1928; Hofker, 1928; and Schmidt, 1931), *Chætoceros* (Gran, 1904; Schiller, 1909; Pavillard, 1914; Henckel, 1925; Gross, 1937/38; and Braarud, 1939) and *Biddulphia* (Bergon, 1907 and Schmidt, 1927, 1928, 1929 and 1933). As regards the remaining genera, viz., *Actinocyclus*, *Bellerochea* and *Cerataulina*, this is the first record of microspore-formation in them.

1. *Coscinodiscus* sp.

In this Diatom, a cell with four rounded bodies was observed at about 12–50 p.m. on 2–12–1942, and was kept under observation in a hang-drop culture. These four bodies, by division (Text-fig. 1), formed eight bodies which by further division gave rise to sixteen bodies by about 1 p.m. (Text-figs. 2 and 3); and by 2 p.m. by

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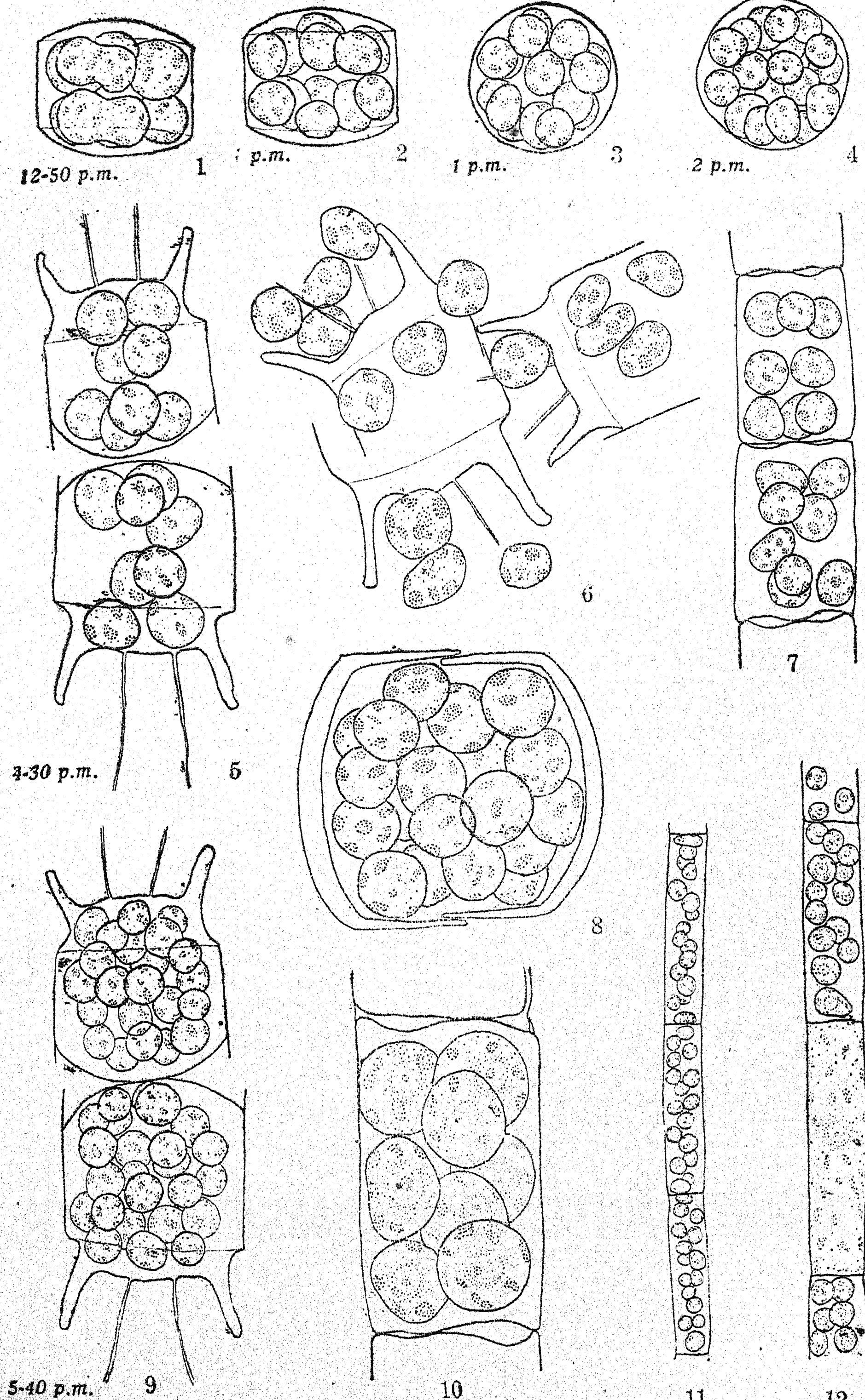

Text-figs. 1 12.—Figs. 1–4. *Coscinodiscus* sp.—Fig. 1. Observed on 2-12-1942 at about 12–50 p.m. Note two of the bodies dividing, some already divided. Figs. 2

and 3. Girdle and valve views of cell showing 16 bodies. All bodies not drawn; about 1 p.m. Fig. 4. 32 Microspores in the cell, about 2 p.m. All spores not drawn. Figs. 5 and 6. *Biddulphia mobiliensis*.—Fig. 5. Observed on 2–10–1940 at about 4–30 p.m. Note 8 bodies in each of the two 'sporangia' of the cell. Fig. 6. From culture; spores inside and outside the cell. Fig. 7. *Bellerochea malleus*, observed on 5–3–1940. Note 2 cells each showing 8 microspores. Fig. 8. *Actinocyclus Ehrenbergii*, observed on 12–1–1941. Cell with 32 microspores all spores not shown. Fig. 9. *Biddulphia mobiliensis*, same cell shown in Fig. 5 at about 5·40 p.m. Each 'sporangium' with 32 microspores, all not drawn. Fig. 10. *Bellerochea malleus*, observed on 5–3–1940, 8 microspores in the cell. Figs. 11 and 12. *Cerataulina Bergonii*, observed on 24–3–1941. Chains showing microspore-formation. One vegetative cell shown in Fig. 12. Figs. 1–4, ×330; Figs. 5 & 9 ×690; Figs. 6 & 10, ×1065; Figs. 7 & 8, ×650; and Figs. 11 & 12, ×225.

another division about thirty-two bodies were formed (Text-fig. 4). These bodies were round and each showed a few chromatophores. No cilia could be observed in any of them though they were very carefully examined. The cell was kept under observation for a long time to observe the liberation of these spores. They did not escape from the cell, but finally they degenerated and died. Microspores have been recorded previously in this genus by Murray (1896), Karsten (1928) and Hofker (1928).

2. *Biddulphia mobiliensis* Bailey

In one of the cells of this Diatom eight rounded bodies were observed in each of the two 'sporangia' which had previously formed in it (Text-fig. 5; Pl. IV, Fig. 1), at about 4–30 p.m., on 2–10–1940. The cell was kept under observation in a hang-drop culture. The rounded bodies in each 'sporangium' then divided and sixteen were formed. Each one of these sixteen bodies again divided and ultimately at about 5–40 p.m. thirty-two spores were formed in each 'sporangium' (Text-fig. 9; Pl. IV, Fig. 2), so that on the whole sixty-four spores were formed in each cell. The spores did not show any further division. Each spore showed a few chomatophores and a nucleus which could be seen on very careful examination. The spores were observed to exhibit some amœboid movement. Though they were kept under observation for a long time they did not escape out of the cell, but finally degenerated and died. These observations agree with those of Bergon (1904) on the same Diatom up to the formation of thirty-two cells in each 'sporangium'. But Bergon observed finally the liberation of these spores as swarmers with two laterally attached cilia. This liberation of the spores as already mentioned was not observed by the writer in the present Diatom.

Again, in some of the old cultures of the Diatom, the writer observed a number of rounded bodies inside and outside the cells (Text-fig. 6). They were isolated into fresh culture media and kept under observation; but they did not show any further development in any one of the cultures. After some time they degenerated and died.

3. *Chætoceros Lorenzianus* Grunow

A few chains of this Diatom showing microspore-formation were met with in the plankton on 2–10–1940. Here each cell of the chain

showed two 'sporangia' in each of which were seen four spores (Pl. IV, Figs. 4 and 5). The spores were somewhat pear-shaped and showed a few chromatophores inside. No cilia could be seen on any of them. They were kept under observation for a long time for watching their liberation. They did not escape out, but finally degenerated and died. The microspores observed by the writer in this Diatom do not at all resemble the microspores recorded by Schiller (1909, Pl. XVI Figs. 10 and 11) in the same species, but resemble very closely the microspores of *Chætoceros decipiens* as recorded by Gran (see Fritsch, 1935, p. 634; figs. 213 I & J). It may also be mentioned here that Schiller observed two types of microspores in this Diatom, small and large ones, so also did Gran in *Ch. decipiens*. But such large and small ones were not observed by the writer.

4. *Actinocyclus Ehrenbergii* RALFS

A cell containing about thirty-two spores was observed on 12–1–1941 and this was kept under observation as in the previous cases. The spores were round and showed a few chromatophores and a nucleus. The spores did not escape out of the cell but finally degenerated and died. Microspore-formation does not appear to have been recorded in this genus previously.

5. *Bellerochea malleus* (Brightwell) VAN HEURCK

A chain of a few cells containing microspores was observed on 5–3–1940 (Text-figs. 7 and 10). Each cell of the chain showed eight microspores and these were similar to those observed in the previous forms. They were round and showed a few chromatophores and a prominent nucleus. The microspores did not escape out but died after some time. Microspore-formation does not appear to have been recorded previously in this genus.

6. *Cerataulina Bergonii* PERAGALLO

Several chains of cells showing microspores were met with in the plankton on 24–3–1941 (Text-figs. 11 and 12). Each cell of the chain showed about sixteen microspores. The number of spores in some of the cells was slightly less, but, in these cases some of the round bodies were larger than the others and probably represented protoplasts about to divide. Microspore-formation does not appear to have been recorded in this genus also.

SUMMARY

Microspore-formation was recorded in six marine Centric Diatoms from the Madras coast, viz., *Coscinodiscus* sp., *Actinocyclus Ehrenbergii* Ralfs, *Chætoceros Lorenzianus* Grunow, *Bellerochea malleus* (Brightwell) Van Heurck, *Biddulphia mobiliensis* Bailey and *Cerataulina Bergonii* Peragallo. In *Chætoceros* and *Bellerochea* eight, in *Cerataulina* sixteen, in *Coscinodiscus* and *Actinocyclus* thirty-two and in *Biddulphia* sixty-four microspores were observed. This is the first record of microspore-formation in the genera *Actinocyclus, Bellerochea* and *Cerataulina*.

The writer wishes to express his indebtedness to Prof. M. O. P. Iyengar, M.A., Ph.D. (Lond.), F.L.S., for his guidance and help throughout the course of this work. His sincere thanks are also due to the authorities of the University of Madras for the award of a research scholarship during the tenure of which this investigation was carried out.

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EXPLANATION OF THE PLATE

Figs. 1 & 2. *Biddulphia mobiliensis.*—Fig. 1. Cell observed at about 4–30 p.m. Note 8 bodies in each 'sporangium' of the cell. Fig. 2. The same cell at about 5–40 p.m. Note 32 microspores in each 'sporangium'. ×640.

Fig. 3. *Bellerochea malleus.*—Note 8 microspores in each cell of the chain. ×750.

Figs. 4 & 5. *Chætoceros Lorenzianus.*—Fig. 5. A chain of cells showing microspore-formation. ×400. Fig. 4. A few cells of the chain under higher magnification. Note 4 microspores in each of the two 'sporangia' of the cell. ×1000.

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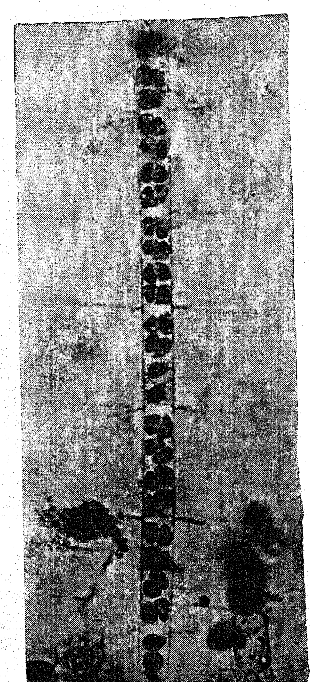

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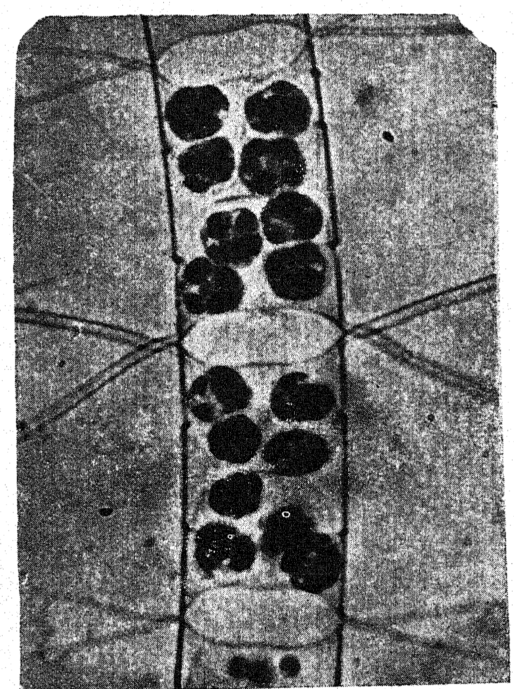

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R. SUBRAHMANYAN—

ON THE OCCURRENCE OF MICROSPORES IN SOME CENTRIC DIATOMS OF THE MADRAS COAST

FEMALE GAMETOPHYTE OF *ACALYPHA TRICOLOR*

BY B. G. L. SWAMY AND B. P. BALAKRISHNA

IT is well known that the family Euphorbiaceæ consists of certain genera that show different types of embryo-sac development. Though considerable amount of work has already been done on the embryology of the members of the family, our knowledge to-day is by no means complete. Particularly so are genera like *Mallotus*, *Acalypha*, etc., whose different species show different types of organisation of the embryo-sac both during development and maturity. For example, *Mallotus japonicus* (Ventura, 1934) develops its female gametophyte according to the *Drusa*-form, while *M. philippinensis* (Thathachar, 1944) develops its embryo-sac according to the *Penæa*-form. Again *Acalypha australis* (Tateishi, 1927) shows the *Penæa*-form ; a species of *Acalypha* according to Arnoldi (1912) also shows the same form ; *A. indica* (Maheshwari and Johri, 1940), an intermediate organisation between *Penæa*-form and *Plumbago*-type, which formation has been termed by the authors as the "*Acalypha indica*-form", while *A. lanceolata* (Thathachar, 1944) shows the *Peperomia hispidula*-form (Johnson, 1914). Hence an investigation of the remaining species of these genera becomes very important. With this idea in mind and also with a view to see if a plant subjected to extreme cultivation shows any anomalies in the development of its female gametophyte, *Acalypha tricolor* was investigated. The results of the investigation are embodied in this paper.

Acalypha tricolor is a shrub, cultivated very commonly as a horticultural plant for its variegated foliage. A considerable percentage of flowers are sterile, but the normal ones produce viable seeds. Material for study was collected from a private garden and slides were prepared according to customary methods.

The young ovule has two integuments, the outer one soon extending beyond the inner one to constitute the micropyle. Later the nucellus grows out of the inner integument in the form of a beak until the obturator comes in contact with it (Fig. 1). Though the presence of a single archesporial cell is the rule, two or three such cells were rarely seen. The primary parietal cell divides in all planes and contributes towards the formation of the nucellar beak.

The megaspore-mother cell after enlarging (Fig. 2) divides meiotically, the four megaspore nuclei usually occupying the four poles (Fig. 3). Each nucleus in this very position divides twice to form a group of four nuclei, three of which organise into cells and one nucleus remains free. The free nuclei belonging to each quadruple group migrate towards each other and fuse to form the secondary embryo-sac nucleus (Figs. 5 and 6). Of the four groups of three

cells, the one situated near the micropyle usually bears a resemblance to the egg apparatus in shape, size, vacuolation and function. However, this distinction is not only frequently absent from the micropylar group, but is often seen in the other three groups as well, in varying degrees. But always the egg of the micropylar group alone is fertilised. The position of the two lateral groups is not always fixed; commonly

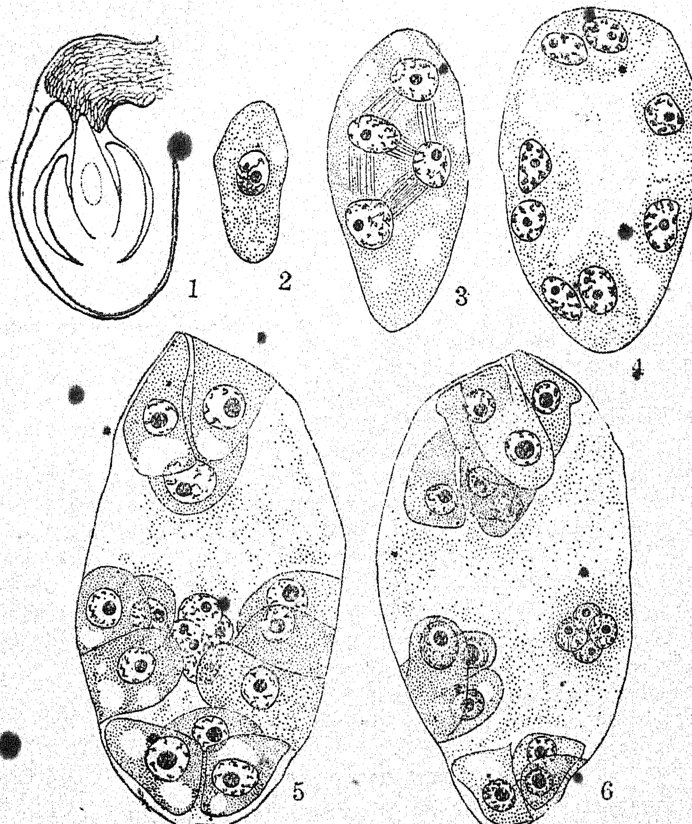

Fig. 1. Longitudinal section of one locule showing the disposition of the ovule and obturator, × 80. Fig. 2. Megaspore mother cell, × 780. Fig. 3. 4-nucleate stage of the embryo-sac, × 780. Fig. 4. 8-nucleate embryo-sac, × 780. Figs. 5 and 6. Mature 16-nucleate embryo-sacs; for explanation see text, × 900.

they occupy the equatorial region of the embryo-sac, opposite to one another; frequently they are found on either side of the antipodal group (Fig. 5); in a few other cases they are seen to be disposed anywhere towards the periphery between the antipodal and micropylar groups (Fig. 6). Whatever may be the individual position of the respective group other than the micropylar one, they degenerate after fertilisation. The cause of the varied positions of the lateral groups was traced back to the respective disposition of the particular

megaspore nuclei at the four-nucleate stage of the gametophyte and no evidence for their displacement after the formation of the quadruple group could be seen.

Conclusion

Acalypha tricolor is a plant subjected to extreme cultivation under horticultural practice by clonal propagation. The embryo-sac develops in a tetrasporic manner and its mature organisation conforms to the well-known *Penæa*-form. The details and sequence of development differ in no fundamental manner from the *Penæa*-form of embryo-sacs, reported in various species of naturally growing Angiosperms. Even the varied position of the lateral groups of nuclei within the embryo-sac does not seem to be a point in favour of the commonly held view that it may be due to cultivation, because this phenomenon is often met within naturally occurring plants also. It has been seen to a marked degree in several wild species of *Peperomia* now being investigated by one of the authors.

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NITROGEN METABOLISM IN RICE LEAVES

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Received for publication on July 23, 1945

The importance of nitrogenous manures to rice plants have drawn the attention of the plant physiologists from the later part of the last century. Earlier works are mainly on the effect of different nitrogenous manures, specially on the relative importance of ammonium sulphate and sodium nitrate and on the absorption of nitrogen at various stages of life. Dastur and Malkani[2] have reviewed all the previous works on rice nutrition in response to different nitrogenous manures studied by Kellner, Nagaoka, Aso and Bahadur, Krauss, Trelease and Paulino, Daikhura and Imreski, Kelley, Harrison, Espino, Shive, Wills and Carrears, and have shown that the rice plant prefers ammonium salt in earlier phase and nitrate salts in later phase of growth. In order to determine the best time for applying nitrogenous manures the rate of absorption of nitrogen has been studied by Kelley and Thompson, Gile and Carreo, Herreo, Suzuki, Sen, and Sahasrabuddhe by analysing the distribution of nitrogen in different parts of the plant at different stages of growth. Sahasrabuddhe[4] has reviewed these works. All workers observed uniform increase in nitrogen content throughout the life but Sahasrabuddhe found two distinct phases of increased rate of absorption, first just after transplantation and the second on the onset of flowering.

All the workers, who have studied the nitrogen content at different stages of growth found that the absorbed nitrogen mainly remains in the leaves. But little attention has been paid to ascertain how the absorbed nitrogen is metabolised in the leaves, a knowledge of which is necessary to understand the physiological processes of the plant. Interesting correlations have been observed by Sircar and Sen[5] between phosphorus deficiency and nitrogen metabolism. The present paper deals with the nitrogen metabolism in the successive mature leaves of rice grown in pots under optimum cultural conditions.

Experimental Procedure

Rice seeds of var. Bhasamanik were selected for uniformity of size and colour, sterilised with 0·2 per cent. formalin and sown in seed beds in field. When the seedlings were 6 weeks' old with 6th or 7th leaf unfolding, they were transplanted to earthenware pots 10″ diam. containing a mixture of fine soil and $\frac{1}{8}$th part of cowdung manure, each pot having one seedling. The pots were kept inside cemented tanks and water level up to the height of the plants was maintained during the course of the experiment. As each leaf on the main axis reached maturity, it was sampled at 6–30 a.m. and taken to the laboratory in glass tubes lined with moist filter-paper and analysed immediately for the nitrogen fractions. Leaf samples of 3rd, 4th, 5th and 6th

leaves were taken from seed beds, while those of 7th to 15th leaves were taken from the pots after transplantation.

The leaves were bisected longitudinally, cut into small bits and weighed. One half was dried at 70° C. for 24 hours and finally at 100° C. for 30 min., powdered in mortar and total nitrogen was estimated in the micro-Kjeldahl apparatus according to Pregl.[7] Reduction of nitrate was carried out by the reduced iron method of Pucher, Leavenworth and Vickery.[8] The other half was thoroughly ground in a mortar to a paste with phenol-water. The extract was filtered through paper pulp and made upto 50 c.c. with several washings of distilled water by using filter pump. Frothing was prevented by adding a few drops of capryl alcohol. Protein was removed from the extract by adding 50 per cent. solution of trichloroacetic acid in the proportion of 1 c.c. acid to 19 c.c. extract and filtering. From the filtrate total crystalloid nitrogen was estimated as before by micro-Kjeldahl method after reduction of nitrate. Protein nitrogen was calculated by the difference between the total nitrogen and crystalloid nitrogen content. Total amino-nitrogen was determined by adaptation of Brown's[1] modification of Sorensen's formol-titration method. Amide nitrogen was estimated by hydrolysing the protein-free extract with sulphuric acid and estimating the ammonia produced by Wolff's method.[9] Regarding amide nitrogen the assumption is made that all amides in the plant exist in the form of asparagine and the absolute values of amino acids are estimated from the difference between total amino and amide figures as has been mentioned by Sircar and Sen.[5] The figures for residual N includes all soluble nitrogen fractions not estimated in any of the above fractions.

Experimental Results

The nitrogen fractions in the successive mature leaves are presented as percentage of dry weight in Table I and graphically represented in Fig. 1 and as percentage of total leaf nitrogen in Table II.

TABLE I

Nitrogen fractions expressed in percentage of dry weight

Leaf No.	Total N	Protein N	Crystalloid N	Total Amino N	Amide N	Amino N	Residual N
3	3·3845	2·7113	0·6732	0·07367	0·05252	0·02115	0·54501
4	2·7355	2·4130	0·3225	0·05848	0·03229	0·02519	0·23083
5	2·4530	2·1702	0·2828	0·05006	0·02752	0·02254	0·20422
6	2·153	1·8773	0·2757	0·03298	0·01631	0·01667	0·22651
7	2·863	2·4766	0·3864	0·11810	0·09003	0·02810	0·17827
8	2·853	2·5469	0·3061	0·07750	0·03959	0·03816	0·18901
9	2·533	2·3127	0·2203	0·05244	0·04089	0·01155	0·12697
10	2·510	2·3062	0·2038	0·04573	0·01965	0·03618	0·13842
11	2·122	1·9555	0·1665	0·0396	0·01732	0·02228	0·10958
12	2·080	1·9226	0·1574	0·01573	0·00347	0·01226	0·12820
13	2·1645	1·9870	0·1875	0·02678	0·00427	0·02251	0·15645
14	1·788	1·5733	0·2145	0·1083	0·02029	0·08801	0·08591
15	1·875	1·6849	0·1901	0·06792	0·0587	0·00922	0·06348

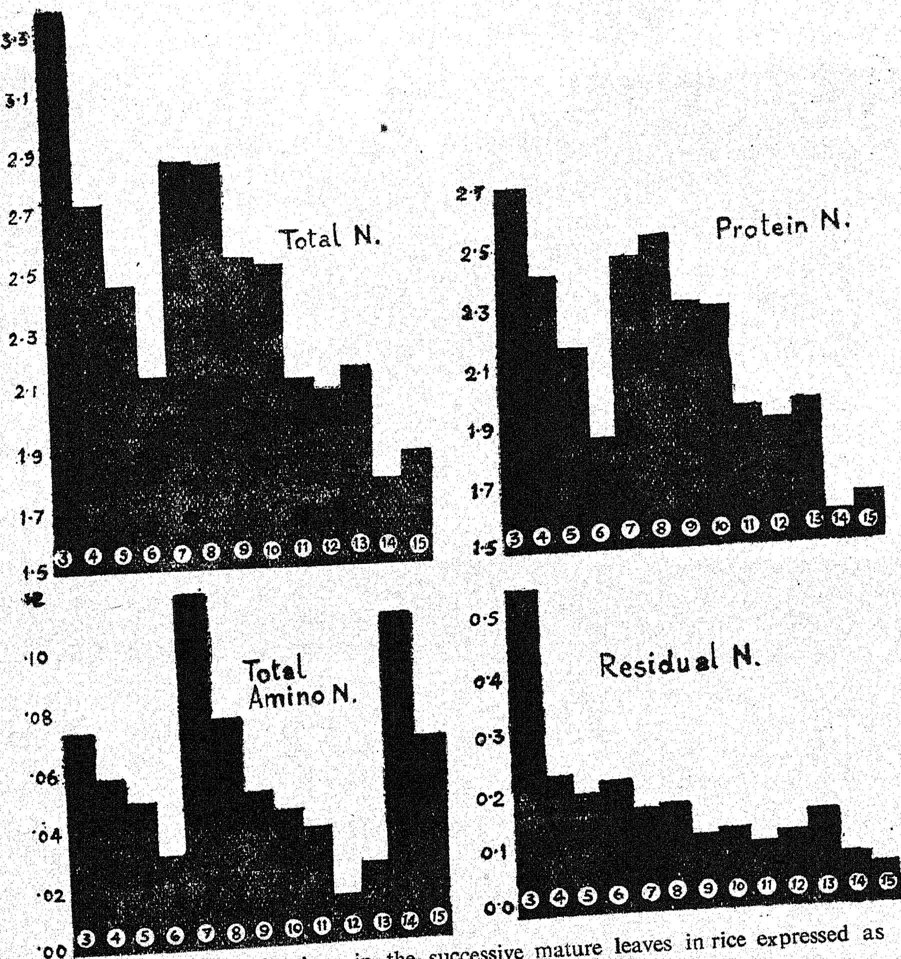

Fig. 1. Nitrogen fractions in the successive mature leaves in rice expressed as percentage of dry weight.

TABLE II

Nitrogen fractions expressed as percentage of total nitrogen

Leaf No.	Protein N	Crystalloid N	Total Amino N	Amide N	Amino N	Residual N
3	80·13	19·67	2·177	1·552	0·625	16·141
4	88·10	11·90	2·138	1·180	0·958	8·582
5	88·67	11·33	2·041	1·120	0·921	8·169
6	91·33	8·16	1·532	0·757	0·774	5·881
7	86·48	13·52	4·122	3·143	0·979	6·255
8	89·24	10·76	2·716	1·388	1·328	6·656
9	91·28	8·72	2·070	1·614	0·356	5·356
10	91·90	8·10	1·822	0·7829	1·0391	5·495
11	92·12	7·88	1·866	0·8156	1·0506	5·1984
12	94·54	5·46	0·756	0·1668	0·5893	4·5371
13	91·81	8·19	1·237	0·1973	1·0397	6·7557
14	87·96	12·04	6·056	1·109	4·947	4·875
15	89·91	10·09	3·622	3·060	0·562	3·408

The nitrogen content as percentage of dry weight decreased in the successive leaves. In the 7th leaf, the first mature leaf developed after transplantation, the nitrogen content increased greatly and almost the same level was maintained in the next leaf. From the 8th leaf onwards a continual fall in nitrogen is seen with a slight increase in the 13th and 15th leaves.

The protein N varied directly as the total N in the successive leaves. It is interesting to note that protein N expressed as percentage of dry weight diminished, while as percentage of total N. increased in the successive leaves. Nitrogen exists mainly as protein, the highest protein level of 94 per cent. being observed in the 12th leaf.

Considerable accumulation of amide N was noticed in the 7th leaf, *i.e.*, after transplantation and again in the 14th and 15th leaves. The quantity of amide N and amino N in rice leaves was found to be very low. The concentration of amino N was generally about 0·1 per cent. of the total N. In the earlier leaves the amino N. content were more or less the same, but after transplantation a rise was noticed in the 7th and 8th leaves and a great irregularity in its concentration is represented in the successive leaves. At the time of ear emergence, *i.e.*, in the 14th leaf an increase in amino N was noticed which is again considerably reduced in the next leaf. A high concentration of residual N was noticed in the 3rd leaf, and in the successive leaves its concentration gradually decreased.

Discussion

In rice plant total Nitrogen content gradually increases after germination with the development of plant. After transplantation plants require some time to settle in the new environment and this is followed by a rapid absorption of nitrogen and vigorous growth in tillering and height. The value of total nitrogen in percentage of dry weight, however, falls with age, reaching a low figure at the time of flowering. Sircar and Sen[5] observed that a high percentage of nitrogen in the mature leaves before ear emergence is associated with the formation of unfertile spike and even to the suppression of ear. The 7th leaf developed after transplantation. A marked increase in its nitrogen content was observed over the next lower leaf, sampled in seed-bed, though the values were gradually diminishing from 3rd to 6th leaf. This suggests a rapid uptake of nitrogen after transplantation as observed by previous workers. The gradual fall in nitrogen level in the successive leaves is more due to the fact that non-nitrogenous dry matters increase much more rapidly. That increase of dry matter in the successive leaves is associated with higher sugar concentration was observed by Ghosh[2] working under similar concentration, and that the rate of sugar-production increased in the later leaves. Nitrogen is mainly present as protein, which gradually increased till the 12th leaf. High protein content of the later leaves suggest increased metabolic activity synthesising the major part of nitrogen to protein. The fall of protein content in the last two leaves (the 14th leaf was sampled when the ears were emerging and the 15th leaf in the milky stage of ear) seems due to the fact that at this stage a considerable amount of protein is

translocated to the rapidly growing ear. One of the most important factor for protein loss in the mature leaves is the formation of young leaves and inflorescences, which act like sink and increase the rate of translocation of nitrogen from the leaves below (Petrie, 1937). With the decrease of protein N at this stage a considerable increase in amino and amide N support the rapid translocation from these leaves. High residual N content, which generally represents the nitrate fraction, in the 3rd leaf is difficult to interpret as Dastur and Malkani[2] observed that rice plants absorb mainly ammonium ion at the earlier stages, and further fractionation is necessary to determine its nature.

Summary and Conclusions

The paper deals with the nitrogen fractions in the successive leaves of rice grown in soil under optimum cultural conditions. A gradual decrease in the concentration of the total nitrogen in percentage of dry weight has been observed in the successive leaves mainly due to simultaneous increase in total dry matter, in much greater proportion. Protein-nitrogen concentration varies directly with the total nitrogen, but while expressed as percentage of total nitrogen it increases in the successive leaves indicating increased rate of metabolism in the later leaves. Rice plants are characterised by low concentration of amino and amide nitrogen. On transplantation a rapid uptake of nitrogen is noticed in the increased nitrogen content in the mature leaves (7th and 8th). This is followed by an increase in protein, amino and amide nitrogen fractions and a vigorous vegetative growth in height and tiller. When the ears are just emerging, translocation of organic nitrogen to this rapidly developing region is indicated by decrease in protein-nitrogen and increase in soluble fractions, specially amides and amino acids in the mature leaves.

In conclusion, I take this opportunity to express my sincere thanks to Dr. S. M. Sircar, under whose care and guidance this investigation was carried out, to Mr. B. N. Ghosh, for his active co-operation, and to Dr. J. C. Sen Gupta, for valuable suggestions and criticism.

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STUDIES IN CROP PHYSIOLOGY

Fertiliser Effects upon Seed Quality, Photosynthesis, Respiration and Chlorophyll Content of Wheat Leaves during Two Successive Generations

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Received for publication on October 10, 1945

Introduction

The present paper attempts to elucidate the responses of wheat plants to the conditions of nutrient supply with special reference to (i) the ontogenetic drifts in photosynthesis, respiration and chlorophyll content of leaves ; (ii) the diagnostic effects, if any, of nitrogen, phosphoric acid and potash upon these plant processes ; and (iii) the lasting or transitory nature of fertiliser effects on the above activities through two successive generations of the crop.

Mineral deficiency is known to induce subnormality in photosynthesis (Briggs, 1922). Nitrogen of all elements has little effect upon CO_2 intake (Gregory and Richards, 1929) though it increases leaf assimilating surface (Gregory, 1926). Its deficiency reduces respiration rate of barley leaves (Gregory and Sen, 1937) but increases assimilation of these leaves (Gregory and Baptiste, 1936), such increases in photosynthesis are usually associated with high sugar content, low respiration, low protein synthesis and low meristematic activity. Application of N on the other hand increases respiration (Hamner, 1936) provided an initial carbohydrate reserve is present ; chlorophyll is also increased (Tam and Magistad, 1935), if other conditions of chlorophyll formation are available. Previous work from this laboratory (Singh, *et al.*, 1939) also indicates the utility of nitrogen in increasing photosynthesis. Association with nitrogen of P and K causes slackening in activity ; the deleterious effect is less, if one of these ingredients is reduced. Presence of complementary factors greatly alters photosynthesis (Singh and Lal, 1940). Nitrogen also augments photosynthesis of sugarcane leaves throughout the life cycle ; respiration is only increased during early stages (Singh, 1941).

Addition of phosphate is also known to increase assimilation rate (Gregory and Richards, 1929). Its importance is felt more during early stages when it invigorates growth and development (Brenchley, 1929). Phosphate supply increases respiration (Lyon, 1923, 1929) but reduces assimilation rate of sugarcane leaves (Singh, 1941). Respiration of these leaves on the contrary, is augmented only during later periods of the life-cycle.

In K deficient cultures respiration is super-normal while assimilation is subnormal (Gregory and Richards, 1929). Increase in assimilation takes place as the level of external potassium concentration is lowered (Richards, 1932). Potash is singly more useful than nitrogen in increasing photosynthetic activity of leaves (Singh, *et al.*, 1939). Assimilation and respiration rate of sugarcane leaves also increases during early periods in response to potash; during late season, assimilation however is lowered (Singh, 1941). Marked differences in chlorophyll content caused by potash have also been noted by Schertz (1929) and Maiwald (1923). It remains however, to be seen as to how far the application of nitrogen, phosphoric acid and potash affects these physiological characters in wheat at successive stages of the life-cycle. Relevant data collected in these directions are presented in the following pages.

Method and Material

The investigation was conducted on wheat (var. Pusa 52) grown in small size (11" × 9") pots, each filled with 10 kgm. of farm soil (sandy loam) and supplied with eight combinations of nitrogen, phosphoric acid and potash as indicated below :—

(i) No manure (C)
(ii) Nitrogen (N)
(iii) Phosphoric acid (P)
(iv) Potash (K)
(v) Nitrogen and phosphoric acid (NP)
(vi) Nitrogen and potash (NK)
(vii) Potash and phosphoric acid (PK)
(viii) Nitrogen, phosphoric acid and potash (NPK).

N, P and K were added at the rate of 24 gm. sulphate of ammonia, 6·6 gm. double superphoshpate, and 4·3 gm. sulphate of potash respectively, per ten pots; treatments were replicated three times. Six plants per pot were grown for the whole of the life-cycle in each of these cultures. Regular hoeing and watering were done to assure good growth.

Measurement of photosynthesis and respiration rates, and chlorophyll content were undertaken on second leaf collected from the top of the primary shoot only. Such leaves were selected at regular intervals of the life cycle from different series of cultures and were kept under laboratory conditions over night. Photosynthesis and respiration rate of such leaves were determined by continuous current method using baryta solution as an absorbent. Chlorophyll content of leaves was estimated on fresh material after Oltman's method*.

Seeds collected from different fertiliser cultures in the first year of the experiment were grown in the next season again in pots filled with farm soil. Each of the eight series of cultures was separately

* *Plant Physiol.*, 1932, 8, 321-26.

maintained. No fertilisers were applied in the second year, and plants were grown under basic level of soil nutrition. Leaves from all the eight cultures were again picked up during the life cycle and their photosynthesis, respiration and chlorophyll content estimated after the manner described above. Assimilation measurements were done under 0·25–0·3 per cent. carbon dioxide concentration, 31° C. temperature and light intensity of 1,500 W. from Phillips bulb maintained at a distance of 18 cm. from the chamber. Heat rays were cut off by a screen of running water interpoused between the bulb and chamber.

Total nitrogen content of grain during two years was also determined by Kjeldahl's method. Percentage of crude protein in these seeds was computed by multiplying total nitrogen values by 6·25.

EXPERIMENTAL FINDINGS

A. Photosynthetic drifts in relation to fertilisers during 1937–38

During the wheat season (1937–38), the rates of photosynthesis of leaves under single fertiliser cultures (N, P and K) showed high values at two stages, one at 30 days and the second at 75 days, in the life-cycle. Relatively, nitrogen exhibited the highest rate of photosynthesis (Table I, Fig. 1) during the period of first maximum ; all other cultures (P, K. and C) did not indicate marked differences amongst themselves but were inferior to cultures supplied with nitrogen alone. At the stage of second maximum, all cultures (N, P and K) were superior to control but individually they did not exhibit any marked differences amongst themselves.

In the two and three fertiliser cultures, the period of high photosynthetic activity was again noticed at two stages, namely 45 and 75 days, in the life-cycle. Relatively higher rates of photosynthesis were recorded at the latter stage when NPK treated plants showed maximum activity. In between these two periods of high activity there was located at 60 days, a period of low photosynthesis in all the cultures.

Statistical analysis of the data showed significantly higher rates of photosynthesis in N treated plants as compared with others. Differences between P and K and between NK and NPK were, on the other hand, not significant at all. Untreated plants were very low in their photosynthetic activity and were followed by PK treated ones. Main effect of N was positively significant ; those of P and K were insignificant. Of all the interactions, N $\times$K was only negatively significant.

B. Respiratory drifts in relation to fertilisers during 1937–38

Rate of respiration of leaves also fluctuated at different stages of the life-cycle under all the treatments. In general, respiration was high during early periods, low during 45–60 days and again high between 60–75 days under majority of the fertiliser cultures (Fig. 1). The overall age values indicate a significantly lower rate of respiration in K treated plants ; in others, the increases or decreases were not significant at all. Untreated plants showed least respiration. All main effects and interactions were insignificant (Table I).

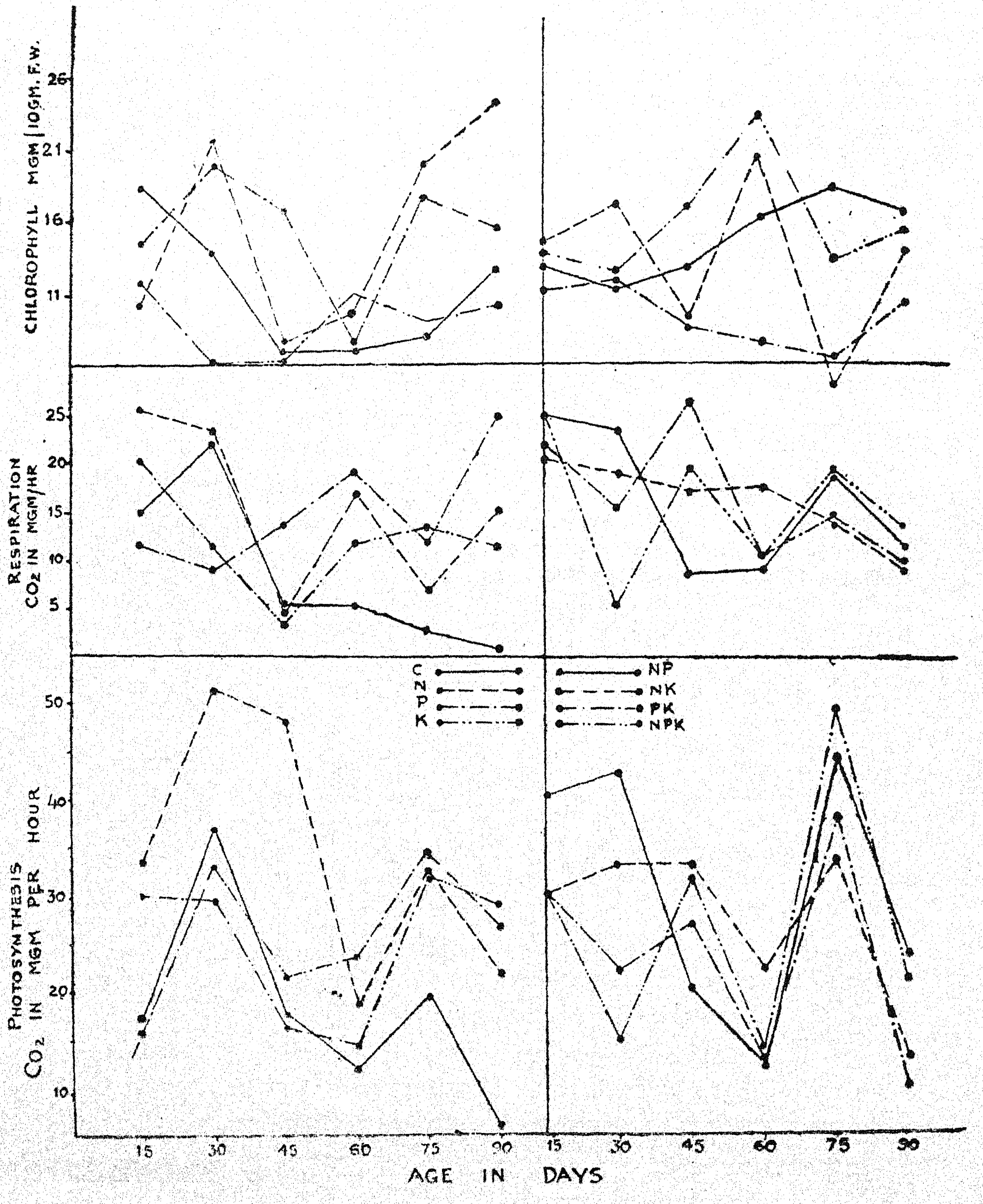

Fig. 1. Photosynthesis, respiration and chlorophyll content of wheat leaves under different fertilisers (1937–38).

TABLE I

Fertiliser effects upon real assimilation, respiration and chlorophyll content of wheat leaves during two successive seasons

Treatments	1937—38		1938—39	
	Mean	M. E. and Int. (Total)	Mean	M. E. and Int. (Total)
Photosynthesis				
C ..	18·2	..	59·35	..
N ..	34·4	+ 162·00**	76·06	+ 16·6
P ..	25·9	+ 6·48	46·80	− 67·0
K ..	25·3	- 36·00	56·10	− 135·8
NP ..	30·1	− 62·22	57·90	+ 10·8
NK ..	27·6	− 89·82*	40·10	− 55·8
PK ..	23·3	− 39·00	58·60	+ 178·4
NPK ..	26·9	+ 77·64	52·20	+ 55·4
C. D.—5% ..	± 7·7	..	±24·2	..
S. E. ..	..	± 44·8	..	± 92·9
Respiration				
C ..	8·75	..	25·10	..
N ..	15·20	+ 62·10	30·55	− 2·16
P ..	15·00	+ 62·34	28·45	+ 2·04
K ..	11·70	+ 33·66	19·75	− 37·36
NP ..	15·59	− 62·04	20·25	− 60·36
NK ..	15·60	− 22·50	18·97	− 0·36
PK ..	15·80	− 17·16	24·12	+ 76·72
NPK ..	15·30	+ 11·70	24·64	+ 69·84
C. D.—5% ..	± 7·5	..	± 19·73	..
S. E. ..	..	± 44·4	..	± 76·12
Chlorophyll				
C ..	11·1	..	22·95	..
N ..	15·5	+ 84·6*	24·82	− 13·16
P ..	15·3	+ 30·0	28·76	+ 8·64
K ..	9·2	+ 56·4	21·45	− 88·44**
NP ..	14·5	− 12·6	24·72	− 17·76
NK ..	13·0	+ 42·0	22·52	− 2·84
PK ..	8·9	− 3·8	18·93	− 37·04
NPK ..	15·6	+ 48·6	18·98	+ 19·56
C. D.—5% ..	± 5·2	..	± 6·22	..
S. E. ..	..	± 31·13	..	± 23·04

* Significant at 5%. ** Significant at 1%.

C. Chlorophyll content in relation to fertilisers during 1937–38

Chlorophyll content of leaves also fluctuated widely from one stage in the life cycle to another. In single fertiliser series high chlorophyll was recorded at 30 days, low at 60 days and again high at 75–90 days in the life-cycle. In the two and three fertiliser cultures, fairly high chlorophyll content was recorded at 60 days in case of NPK and NK cultures. Plants supplied with PK consistently showed a decline till 75 days and only exhibited a rise at 90 days (Fig. 1). All treated cultures except PK and K were higher in chlorophyll than the control. Chlorophyll content of N, P and NPK treated wheat was high ; differences between these treatments were not significant at all. Main effect of N was however only significant (Table I).

D. Effect of age on physiological drifts during 1938–39

The effect of age on physiological drifts during 1938–39 was more or less of a similar nature in all the series of cultures. Treatment with any nutrient in the previous life cycle brought about only slight variation in photosynthesis, respiration and chlorophyll content of leaves during the following season. Photosynthesis showed an increase from 30-60 days in seven out of eight cultures reaching a maximum at 60 days and subsequently showing a decline (Fig. 2). This fall towards the end of the life-cycle was characteristically noted in all cultures. Respiration also exhibited high values at 30 days in case of K, NP and NK cultures; in others high carbon dioxide output was recorded only at 60 days. This more or less coincided with the maximum obtained for photosynthesis. Decline in respiratory activity with age was also uniformly noted in all the cultures (Table I).

On chlorophyll the effect of age was slightly different from that of respiration or photosynthesis. Leaves continued to exhibit increasing chlorophyll content with advance in age till 120 days in the life-cycle.

TABLE II

Age effects upon photosynthesis, respiration and chlorophyll content of leaves (1938–39)

Age in days	mgm. CO_2/100 sq.cm.		Chlorophyll mgm./10 gm. f.w.
	Assimilation	Respiration	
30 ..	75·62	42·64	15·73
60 ..	106·10	39·88	21·94
90 ..	26·87	7·9	25·44
120 ..	15·92	7·56	28·46
Critical difference ..	± 17·22	± 14·11	± 11·65

The overall treatment values indicate the effect of age to be significant at almost all stages of growth in case of photosynthesis. In case

TABLE III

Protein content of seeds under different treatments during two successive generations

Treatments	Protein content 1937–38	Protein content 1838–39	% Decrease
C ..	13·75	5·0	63·6
N ..	21·63	9·38	56·6
P ..	13·00	6·06	53·39
K ..	14·31	3·93	72·54
NP ..	14·56	7·18	50·63
NK ..	14·12	6·56	53·55
PK ..	13·00	4·37	66·39
NPK ..	14·56	7·50	48·50

TABLE IV

Average meteorological conditions at Benares during growing season (October–March) 1937–38 and 1938–39*

Meteorological factors	1937—38*	1938—39*
Mean dry bulb temp. 8 hrs. L.M.T. ..	64·08	63·8
,, wet ,, ,, ..	57·78	57·60
,, dry ,, 17 ,, ..	77·23	79·03
,, wet ,, ,, ,, ..	63·06	62·83
,, daily Max. Temp. ..	81·75	82·91
,, ,, Min. ,, ..	56·41	58·28
,, R. H. at 8 hrs. L.M.T. ..	67·83	68·0
,, ,, 17 I.S.T. ..	45·0	38·33
,, daily wind velocity M.P.H. ..	47·33	44·0

of respiration, significantly higher rates were recorded during early stages only. Age significantly increased chlorophyll content only beyond 60 days in the life-cycle (Table II).

E. *Treatment effects on physiological drifts during 1938–39*

Taking overall age values into consideration the rate of photosynthesis was found to vary from treatment to treatment (Table I). Least photosynthesis was recorded under NK treatment and highest under N; differences between these two were statistically significant. All other cultures did not differ significantly either from the values recorded for N or NK treated plants.

Respiration was highest under nitrogen and lowest in case of NK (Table I). Both these cultures did not differ significantly amongst themselves. Nitrogen, however, was not significantly superior to others.

* Average value calculated from the data kindly supplied by the Director-General of Observatories, Poona.

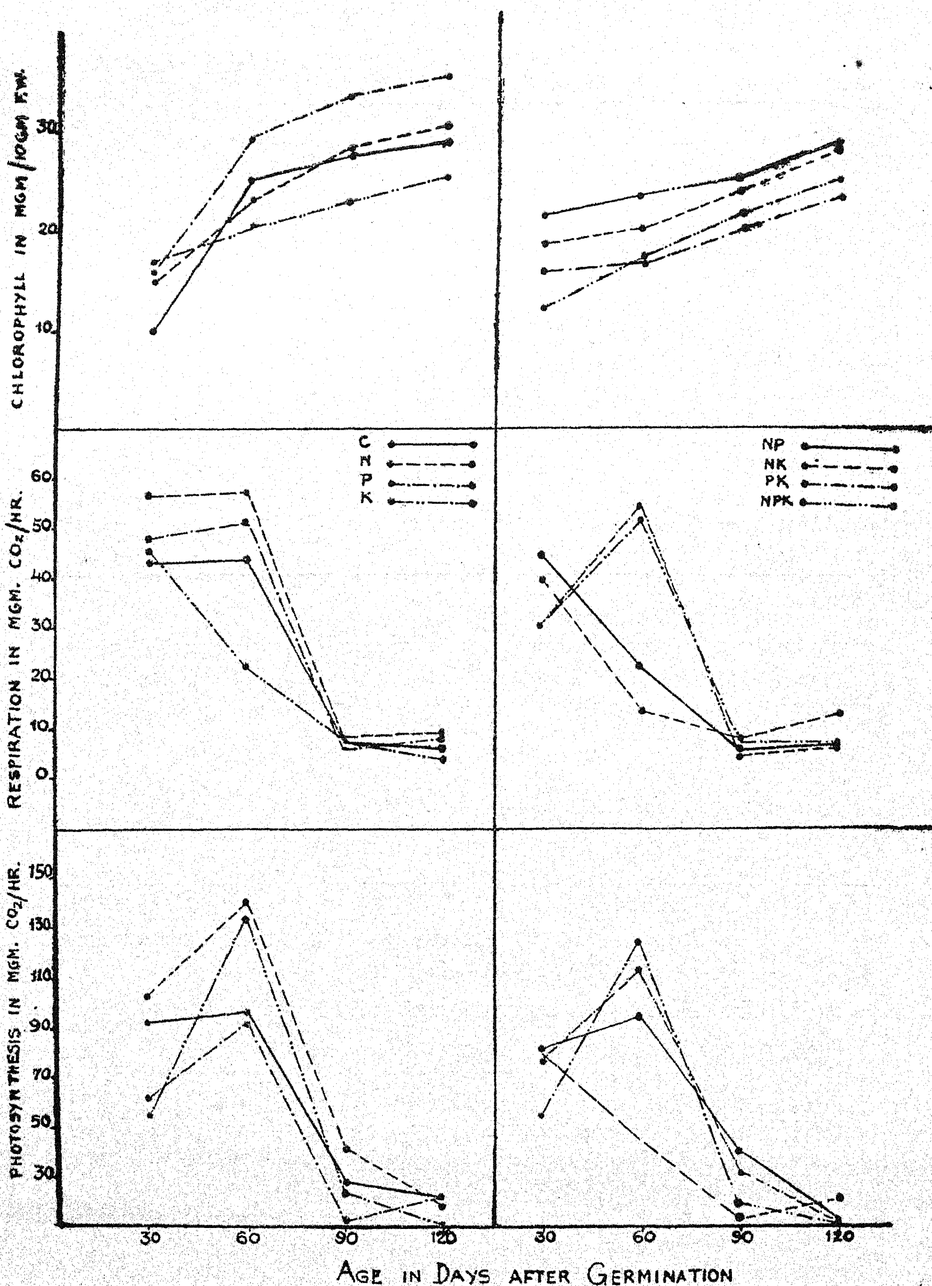

Fig. 2. Photosynthesis, respiration and chlorophyll content of leaves in different cultures (1938–39).

The effect of fertilisers on chlorophyll was slightly different. P treated plants were highest in chlorophyll followed by N. Differences between the two were statistically insignificant. NPK and PK treated plants showed the least chlorophyll content and were significantly inferior to only the P cultures in this regard.

All main effects and interactions were, however, insignificant in case of photosynthesis and respiration. On chlorophyll potash only exhibited significantly deleterious effects.

F. Protein content of grain during two generations 1937–38 *and* 1938–39

Protein content of grain during the first year of the experiment varied from a maximum in the N treated plants to a minimum in the P and PK treated plants. No marked differences amongst different treatments (except N) were discernible. In the second year of the investigation when the seeds collected from differently treated pots were sown under basic level of soil nutrition the protein content of the grain varied more characteristically. Nitrogen applied alone in the previous year showed the maximum protein content followed by NPK and NP cultures while K exhibited the least protein (Table III) in the second year of experiment.

Percentage decline in protein content in the second generation amounted to more than 50 per cent. in majority of the treatments. Full fertiliser (NPK) treatment showed the minimum decline in the second generation while seeds from K exhibited the maximum fall. The reductions were of the same order in case of N, P and NK treatments. Control and PK treated plants were midway between the K and N treated series.

Meteorological records during the growth period of wheat during the two successive seasons indicated more or less identical climatic conditions (Table IV). Relative fall in the protein value of the grain during the second season, therefore, gives indication to the view that better quality of seeds once induced as a result of fertiliser application cannot for all times be maintained in the next generation if the plants do not receive any nutrients during their development. The effect of nutrition appears to be of a transitory nature, affecting the metabolism of cells and not interfering to any marked degree with the genetic constitution of the seeds produced. If quality is to be maintained, each successive generation of plants need receiving adequate fertiliser dressing.

Discussion

Data recorded in the previous pages indicate, in general, the importance of age in inducing high or low photosynthetic activity. Depending upon the quantity of nutrients added, however, differences in magnitude of photosynthesis at majority of stages and in particular during periods of high activity were noted. The mean life-cycle values under a particular fertiliser ingredient indicate the importance of nitrogen in increasing the photosynthetic efficiency of leaves. This is in conformity with the results obtained earlier (Singh, 1941) where

it has been pointed out that in sugarcane, nitrogen increases assimilation rate throughout the life-cycle. Nitrogen thus in both the crops (wheat and sugarcane) has an augmentative effect upon this physiological process.

On respiration and chlorophyll content, as the main effects and interactions indicate, none of the ingredients, N, P and K, showed any significant response although the data in sugarcane (Singh, 1941) indicated the importance of nitrogen and potash in increasing photosynthesis and respiration both during early stages of growth. For obtaining best response from the point of view of photosynthetic activity of wheat leaves it appears, therefore, that its supply should be assured sufficiently early in the life-cycle long before the attainment of the first maximum at 30 days. From the point of view of these characters, P and K do not appear to be of so much importance in these soils.

No conclusive view could be advanced in the light of the above observations upon the role of N, P and K upon respiration and chlorophyll content of leaves although the recent researches of Gregory and his school (1926, 1929, 1936, 1937) point out the profound influence that N and K have upon the respiratory drifts in barley leaves. Significant reductions in respiration rate in N deficient cultures and significant increases in the same activity in K deficient series were recorded by Gregory and Sen (1937). The data further reveal that the effect of fertilisers is not necessarily of a lasting nature inasmuch as seeds raised under different fertilisers when sown under one nutritional condition in the subsequent season hardly, if ever, indicate differential photosynthetic activity at various stages in the life-cycle; so were the effects in case of respiration. On chlorophyll deleterious effects were noticeable in plants raised from seeds of K series of cultures. Lower chlorophyll content in this series was also accompanied by greatest reduction in protein content of the grain in the second generation. These facts give evidence to the necessity of proper fertiliser rationing during successive cropping seasons if seeds of good quality (high protein content) are desired.

SUMMARY

In the previous pages have been discussed the effect of N, P and K application upon ontogenetic drifts in photosynthesis, respiration and chlorophyll content of leaves during two successive seasons. The experiments were conducted in pots filled with farm soil (sandy loam) as the medium of growth.

Photosynthetic activity of leaves was significantly increased in response to N fertilisation. On respiration none of the fertilisers had any significant effect. On chlorophyll main effect of N was only significant.

Two periods of high photosynthetic activity were recorded, one during early stages (15–30 days) and the other during later periods (60–75 days). On chlorophyll the average effect of age was to increase chlorophyll content till 120 days. Significantly high photosynthetic

rates at majority of stages, high respiration rates during early periods and high chlorophyll content beyond 60 days were the characteristic responses of age upon these characters.

No significant differences in photosynthesis and respiration during the second generation in response to fertilisers applied during previous life-cycle were recorded. On chlorophyll seeds raised from K alone exhibited significant reductions during the second season.

Protein content of seed was decreased in the second generation in all cultures irrespective of whether the plants were raised from seeds produced under one or the other of the eight combinations of N, P and K.

Significance of these results has been discussed.

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276-46—Printed at The Bangalore Press, Bangalore City, by G. Srinivasa Rao, Superintendent

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